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The habits of Queensland fruit fly in winter: *Using this knowledge to manage Queensland fruit fly*

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FINAL REPORT – 13 DECEMBER 2017

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FOR: Moira Shire Council, Cobram & District Fruit Growers Association

1. PROJECT TITLE

Project 2 - Queensland fruit fly research on the habits of the pest during the winter months and how they can be better targeted during this period

2. PROJECT AIM

To ascertain where flies overwinter and in what life stage/s with a view to targeting these pests then, rather than later in the season after pest populations have built up. The aim is to reduce pest fruit fly populations in the Cobram District to below economic thresholds which, if successful, will benefit the district's production (commercial and home-grown) and export of their horticultural produce.

3. PROJECT BACKGROUND

Over the last few years the Queensland fruit fly (*Bactrocera tryoni*, Froggatt) (Qff) has invaded and established permanent populations in regions of Victoria and southern NSW where, previously, it was unable to. Whether global warming, insect acclimatisation, reduction in the number and range of approved pesticides or combinations of these are at fault it is of little consequence as the pest now impacts heavily on these regions. The presence, or likely presence, of Qff in these areas has caused significant adverse impacts on both horticultural productivity and horticultural exports.

Trapping with parapheromone lures and associated arrestants is generally regarded as the most effective way to monitor commercial orchards, communal areas and backyards for presence, and subsequent proliferation, of pest fruit flies. Knowledge of the timing, location and volume of flies found in traps assists in strategic management of these pests to maximise horticultural production. Consistent absence of flies in traps aids in proving the existence of Pest Free Areas for facilitated market access.

Recently, at least two more trapping systems have come onto the market, both of which target the trapping of female fruit flies rather than male flies as is the current practice. As it is the female fly which causes direct damage to crops marketing these female-biased systems has a significant role in regional fruit fly management. These systems can be used in addition to, or, in sensitive situations such as urban areas, to replace fruit fly baiting.

Trapping systems are only part of the solution. We need a better understanding of what pest fruit flies are doing throughout the year and use this information to better target the pest. With this knowledge, we can place traps and baits in areas where flies are more likely to be at the most opportune times of the year. Strategic fruit fly mitigation systems will reduce financial costs as well as adverse environmental impacts and could well lead to either proof of zero pest populations (i.e. a Pest Free Area) or an approved Systems Approach to fruit fly control.

4. BIOLOGY AND ECOLOGY OF THE QUEENSLAND FRUIT FLY

The adult fly is not often seen but if there are some around and you stay still for a while near a fruiting tree you should see them fly in and land on a leaf or fruit.

Generally adult Qff range in size from 7mm long and 14mm wide, with wings outstretched, to 8mm by 16mm.

The adult Qff is reddish brown to dark brown and more wasp-shaped than shaped like a house fly having a narrow waste between the thorax and the abdomen. The thorax is decorated with two shoulder patches, two long stripes and various patches on each side. Patches and stripes can range from bright yellow, through cream to, less commonly, white.

In the orchard, the adults fly away from their overnight resting place when it is warm, and/or sunny enough to find water and food. Females start to look for a suitable fruit to lay her eggs into and males start to look for a suitable place from which to “call” or attract potential female mates to. During the middle of the day, depending on temperature and relative humidity, both males and females rest under large broad leaves. Later in the day the females travel to the males and mating may occur in the late afternoon, just before dark.

Males attract females by positioning themselves in a suitable tree. Such trees may have fruit on them or may be just large and dark, and therefore, cool, humid and safe. Often several males will pick the same tree and join in together to attract females. They do this by emitting a sex pheromone that they release from their bodies and beat with their wings to disperse it on the breeze. The sound of their wings is called “stridulation” and females will use the stridulation to home in on the males after initially detecting the scent of the sex pheromone. Once the female enters the site of the group of males – called the “lek” - the males then proceed to perform courtship dances. Quite often the male is on the topside of a well-lit leaf and the female under it. She can “see” the shadow of the male’s movements through the leaf. She then chooses her mate based on the courtship dance.

Adult Qff need water which they obtain from dew, nectar and rain; sugar from nectar and other plant exudates and protein from yeasts and fungi which grow on plant surfaces, bird droppings, etc. Female flies need protein to help their eggs to mature. Male flies need protein to become sexually mature.

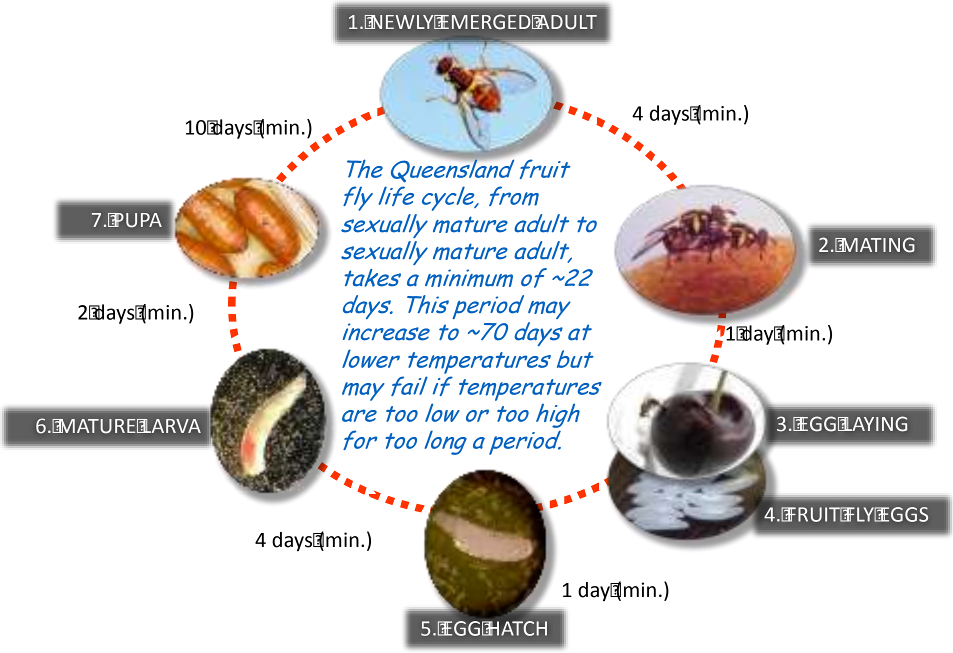

Figure 1. Life cycle of the Queensland fruit fly at optimum development temperatures (between 25˚C and 29˚C)

Adults

Usually, male and female Qff mate at about 4 to 10 days after breaking out from their pupae. After mating the female Qff can lay fertile eggs within a day. She can lay more than 2,000 eggs in her lifetime after just one mating. If the female is to survive a cool winter she may have to resorb her fertilised eggs for energy as she will not move very far in the cold. To lay more eggs, then, she will have to mate again when the weather warms up again in spring.

The female will mate between one and three times during her lifetime. Males will mate many times.

Eggs

Depending on the temperature in and around the fruit Qff eggs will hatch in 24 to 48 hours from egg laying. If the wound around the eggs dries out the eggs may desiccate and not hatch at all. This often happens in avocadoes and purple passionfruit. Eggs are laid close to the fruit surface, usually less than 4mm deep because that's about how far the female can extend her ovipositor (the "stinger"). If the fruit's skin is very thick, such as you may get in coastal oranges, and the eggs are laid only in the skin and not in or near the flesh the eggs can desiccate and die. If there are many flies trying to infest just a few fruit one fly will lay her eggs into the hole another fly has made. The first fly's eggs may then be pushed deeper into the fruit than 4mm.

Eggs are injected into the fruit accompanied by cultures of several fungi and bacteria that attack fruit tissues and cell walls, digesting them down to simpler, more easily ingested proteins and amino acids. Newly hatched larvae feed on these.

Larvae

The newly hatched larvae are close to the fruit surface but as they ingest more fruit tissue they head down towards the fruit centre. If the fruit is very juicy the larvae may not penetrate very far because they need to have access to air to enable then to breathe. If you open an infested, but very juicy, fruit you can see all the larvae together with their heads buried into the juicy flesh and their tales poking up out of the ooze. Their posterior spiracles, which they use to breathe, are located there.

Fruit fly larvae go through three stages inside the fruit. Depending on temperature and what sort of fruit they are infesting, the first stage larvae, or first instar, lasts about 2 or 3 days. During this time, the larvae feed and grow from about 1.2mm to about 2.2mm. When they reach this length, they stop feeding and moult. They shed their skin like a snake and a new one hardens. They are now at the second instar larval stage. Second instars grow from 2.3mm to about 4mm over about two days and they tend to be as close to the centre of the fruit as possible. Then they stop feeding again and moult into the third instar. The third instars grow from 4mm to 8mm over another two to three days. The third instars now move to the fruit surface and by the time they reach it it is time to hop out and pupate in the soil or leaf litter below their host plant.

Larvae live inside fruit for 6 to 20 days or more depending on temperature and what sort of fruit they are growing in. Cherries, for instance allow fruit flies to grow quickly but some apple varieties make them grow quite slowly.

Pupae

Pupae remain in the soil for 8 to 15 days before the adult fly breaks out, again depending on the temperature. Some observers have found pupae remaining viable for a month or two in the ground or even in mummified fruit in winter.

5. EFFECTS OF GEOGRAPHY AND CLIMATE ON THE QUEENSLAND FRUIT FLY

District

Fruit flies can be a pest all year round if environmental conditions allow. Parts of coastal Queensland can be warm enough for fruit flies to remain sexually active all year. The further inland or the further south you go the fewer generations of flies you get each year. Some fruit fly species are less tolerant of cool conditions and so will not move very far south. For example, the Lesser Queensland Fruit Fly will not venture much further south than Coffs Harbour on the Mid North Coast of NSW. The cucumber fly cannot be found further south than Brisbane in Queensland. The limiting factors, here, are temperature and relative humidity. If the temperature remains above about 20°C all day and most of the night all year then it is possible to have a fruit fly problem all year. Twelve generations of Queensland fruit fly a year are possible in these districts.

Cooler districts on coastal NSW around Sydney may allow only 5 of 6 generations of Queensland fruit fly a year while areas with even cooler winters, such as Young, a cherry production area in southern NSW, allow only 2 or 3 generations a year.

In some districts winters are so cold that all fruit flies are killed by exposure to the cold and the insect dies out. The Murrumbidgee Irrigation Area of NSW and Tasmania are examples of this sort of climate. Flies can build up again in these areas by two ways. Firstly, if last winter was relatively mild then adult flies can survive and then re-mate and build up again the following Spring. Alternatively, new flies might come into the area in infested produce being brought in. This causes an outbreak of new flies and the start of a new population of fruit flies for that region as the weather warms up.

Time of year (winter, Christmas)

As mentioned before some districts have pest populations of fruit flies all the year. Other, generally cooler, areas can get away with producing crops in the late autumn to spring. In Sydney, after a normally cool winter, tomatoes can be grown fruit fly free if planted early so that fruit ripens before Christmas. Generally, cherries from Young are harvested before Christmas and, most often, do not need to be treated against fruit flies.

If flies are to survive the winter, they generally over-winter as adult flies. In rare circumstances when the winter is mild and the level of natural predation (such as fowls and other insect-eating birds, predatory insects and parasites) is low some insects may survive as pupae. These circumstances would be unlikely except possibly in a monoculture but chemical applications would kill off over-wintering pupae (and adults). Another possible mechanism for over-wintering of fruit flies is at the larval stage. This can occur on some fruit that persists on the tree over the winter. The main culprits are apples and quinces. Even when old and shrivelled some of these fruit are moist enough to host live fruit fly larvae. There have been no records, however, of fruit flies over-wintering in winter persimmons or pomegranates.

If you have several heavy frosts in a row any over-wintering adult flies, pupae or larvae in the area may die out. But frost is not completely uniform in its severity. It is possible that fruit growing near houses or under trees will be warmer than other more exposed situations and adult flies may survive there. If infested fruit have been disposed of in a compost heap near the end of autumn larvae, pupae and adults may survive in the warmth there. This last scenario is not particularly likely because many predators would be over-wintering or visiting there too.

In areas with mild winters fruit flies will survive the winter months and then be ready to explode in numbers as soon as the weather warms up in late winter and spring. This is a very dangerous situation for subsequent crops. Generally, as the nights and mornings cool down as winter approaches flies tend to migrate to warmer positions in the orchard or surrounding urban areas or bush land. At this time of year adults will not travel very far – only a matter of 800m at the most. At the start of cool weather flies will not fly at temperatures less than about 20°C but, being very adaptable, they will acclimatise to cooler temperatures and be able to fly at temperatures as low as about 10°C.

But they will not mate at temperatures below about 20°C. Because flies mate only near sunset and temperatures at that time of day are generally cooler than 20°C in the winter in most areas there will be no mating. If the winter is cool enough the females will resorb any fertilised eggs back into her system in order to survive. When this happens she needs to mate again in the spring. If the winter is mild enough the female will hold onto her fertilised eggs through winter and be able to infest suitable fruits, if available in her vicinity, as soon as the weather is amenable in late winter. If there are ripe fruit available at that time and precautions are not taken, then fruit fly populations will expand rapidly.

Weather (rain, humidity and temperature)

Weather cannot be predicted very accurately, especially in coastal Australia. Fruit flies do react to weather, though. Fruit fly problems will be lessened during extended droughts. Flies regain problem status quite rapidly after rain. This implies that flies are not killed during droughts. They are just not laying eggs – they are waiting for more favourable climatic conditions in which their offspring will have a better chance for survival.

Large pre-winter population

If a large population of fruit flies has been able to build up over the months just prior to winter the chance that a potentially damaging population will survive over winter to infest next season's crops is improved. Flies that survive the winter are the ones that infest spring crops or produce offspring that infest late spring and summer crops. If the winter is unseasonably warm and wet, as it has been over the last ten years or so in south-eastern Australia, fruit fly survival over winter is enhanced. It is important to ensure that flies do not build up before winter.

Conditions that favour this build-up include:

1. Warm, wet winter
2. Cool summer
3. High infestation rate in previous season's crop
4. Inadequate clean-up of last season's crop allowing flies to infest fallen and late-hanging fruit
5. Inadequate removal of feral and weed fruit fly host plants

6. Inadequate maintenance of weeds that provide refuge for overwintering flies

Growers cannot do much about points 1 and 2 above except to note if these weather conditions have occurred and plan ahead for a possible influx of fruit flies into their orchards in spring. Intercepting these flies with early placement of monitoring traps and fruit fly baits, if necessary, will pay dividends in fruit fly management over the following season. This is explained more fully in the section on Pest management.

6. VICTORIA'S FRUIT FLY HISTORY

Pest fruit flies are not native to the State of Victoria. All pest fruit flies that have been recorded, from time to time, in Victoria have been due to human-aided incursions. Recently observed over-wintering populations of Qff have become established in Victoria, including in and around Cobram, due to a combination of reduced pest control options, the pest's innate ability to adapt to new conditions and, possibly, changes in climate.

Mediterranean fruit fly (Medfly)

The first incursion of pest fruit flies into Victoria was the non-native Mediterranean fruit fly (Medfly) (*Ceratitis capitata*). Medfly was first found in Australia in 1895 in Claremont, near Perth, Western Australia (Jenkins, 1946) or in October/ November 1896 in Guildford, also near Perth in late hanging limes (Fuller, 1897). Fuller (1897) also states that "*peaches and apricots, and, to a lesser extent, figs and citrus fruits, are the particular sorts that have suffered*".

It was described by French (1907) as "*This terrible scourge of the fruitgrower is becoming but too familiar in Victoria, the larvae having been found in peaches, pears, quinces, apricots, plums, nectarines, guavas, oranges, lemons, apples, citrons, loquats, mangoes, pumpkins, bananas, tomatoes, pineapples, and persimmons; so that it will easily be seen that hardly any fruit can be said to be exempt from its attacks, and of all the fruitgrower's enemies the fruit-fly is undoubtedly the worst*."

Medfly caused very serious damage to crops in some years early in the twentieth century in Victoria. However, its presence in Victoria was sporadic over the years with zero impact in some years and serious impact in others. By 1912 it was suggested that "*Our climatic conditions do not appear to be entirely suited to their development. Doubtless many of the larvae were imported into Victoria in oranges and bananas before the present system of inspection was instituted, but they do not appear to have survived and multiplied*" (Anon, 1912). Observations, from 1907 to 1912, of the presence of Medfly in the Goulburn Valley reported that Medfly had "*done comparatively little damage*" (Anon, 1912). Despite so many possibly infested fruit being exported into Victoria from Medfly infested areas in NSW and Queensland (although scientists dispute that Medfly ever made it to Queensland) (Tryon, 1926) it was surprising that Medfly did not establish in Victoria.

Later, in January/ February 1924, however, Medfly did become more problematic in Victoria where it was found in 120 orchards in the Mildura region (reported as the "Mildura Manifestation" by Tryon, 1926) and then in March 1924 in the Goulburn Valley. Outbreak conditions were declared in Mildura, Shepparton and some places in north-eastern Victoria (O'Loughlin, 1964). Fly numbers were quite low in these regions except in one place on the Murray River some 5 miles from Cobram where there was 100% destruction of peaches due to Medfly (Ward, 1924). A serious of control measures were instigated as a result of the outbreaks in Cobram and Shepparton in 1924 including processing fruit at the local canning factory so that all fruit were processed by April 8, as well as disposal of infested fruit and then destruction of subsequent second crop oranges and any other crops allowing a significant gap between those fruit and next season fruits (*Australasian*, 1924; *Argus*, 1924).

At this time home garden orchards in urban areas near commercial horticultural regions were targeted by Government regulation. It became a legal requirement that owners of gardens with fruit fly host material (as well as other pests and diseases) "*shall take all such measures ad do all such acts as are prescribed by these regulations, or such other measures of acts as an inspector orders to be taken for the effectual treatment*" of affected plants. Failure to act accordingly risked fines of up to £20. (Regulation No. 2 of the Vegetation and Vine Diseases Act, 1928 as cited in the *Weekly Times*, 1936).

Medfly died out from Victoria and, indeed, from the rest of the East Coast of Australia with no Medfly being found after 1941, except for some found in Bolton Street, Beaumaris, a suburb of Melbourne, in 1953 (*Age*, 13 February 1953).

Queensland fruit fly (Qff)

The Queensland fruit fly (Qff) is said to be a native of south-east Queensland and north-east NSW. It was reported as a serious pest of fruit in northern New South Wales as early as 1852 (O'Loughlin, 1964) although such an early date is debated by scientists. Qff was first detected in Victoria in 1946 in East Gippsland (O'Loughlin, 1964). In 1953, an infestation was detected in Westbury Street, East St Kilda, a Melbourne suburb (*Age*, 13 February 1953). O'Loughlin (1964) also states "*During the following ten years, the fly has been recorded from some Melbourne suburbs, numerous places in East Gippsland, several towns in north-eastern Victoria and from the Mildura area*".

Qff has plagued Victorian growers on and off for many years since 1946. By 1948 Qff had been found in a number of locations from Sale, through Bairnsdale, Bete Bolong, Weeragua and Mallacoota. Populations and outbreaks waned until 1954 then exploded again in 1955 with outbreaks occurring in Thoona, Chiltern, Wangaratta, Albury and other places in the north of the state; Pascoe vale and Kew in Melbourne;

Mallacoota, Combienbar, Buchan, Swifts Creek, Tambo Crossing and other places in the east (O'Loughlin, 1956).

By 1983, Qff was present in the following parts of Victoria: Gunbower, Koondrook, Mildura, Tol Tol in N.W. Victoria, 15 towns in north central Victoria, 22 towns in north east Victoria, 30 suburbs of Melbourne and 17 towns in West and East Gippsland (Kinsella, 1983).

From 1972 to 1982 there were 168 outbreaks in the Gippsland region, 10 in the South West, 55 in the North East, 45 in the North Central and 6 in the North West (a total of 284 outbreaks of Qff in Victoria during the decade from 1972) (*Review of fruit fly Control in Victoria*, 1992).

From 1975/76 to 1989/90 there were only 9 Qff outbreaks in the Sunraysia district of Victoria. Of the 110 male flies trapped in Sunraysia from 1975 to 1990 over 50% of these were found in and around Swan Hill and over 90% were trapped between January and June (DARA, 1990). For more detailed assessments of these outbreaks please see *Fruit Fly Control in North West Victoria: Review of Procedures for Prevention and Control*, Department of Agriculture and Rural Affairs, Victoria, June 1990.

From 1982 to 1992 there were 67 outbreaks in Gippsland, 27 in the South West, 49 in the North East, 16 in the North Central and 18 in the North West (a total of 177 outbreaks of Qff in Victoria during the decade from 1982) (*Review of fruit fly Control in Victoria*, 1992).

From 1992 to 2002 there were only 36 outbreaks in Victoria but from 2002 to 2008 the number of outbreaks in those 6 years rose to 91 (Kalang, 2008). In the year to 3 August 2009 there were 34 outbreaks in Victoria (Victorian Department of Primary Industries, 2009). In 2011 there were 116 outbreaks in Victoria (ABC News, 14 October 2011). As at 19 December 2016 there were 194 Qff outbreaks in the Greater Sunraysia Pest Free Area alone (DEDJTR, 2016). This had increased to 204 in the same area by 16 March 2017 (DEDJTR, 2017)

Between 1949 and 2012 the Victorian State Government undertook the responsibility to eradicate QFF and Medfly incursions as they occurred. During those years, it was thought that Qff could not establish itself in Victoria due to cold winters and hot, dry summers. Despite this O'Loughlin (1956) suggested that Qff could develop a cold-hardy strain that would overwinter under Victorian climatic and geographic conditions. In 1984 O'Loughlin published results from studies he and co-workers carried out on the potential for Qff to survive more than one generation in Victoria. They showed that "*Field cage studies in Melbourne, of cohorts started each month as eggs, pupae and teneral adults, indicated that adults emerging from mid-April to mid-May could survive to breed in the following spring. It appears that adults* *emerging earlier would not survive to produce eggs in spring, and that adults would not be expected to emerge later in autumn because the survival rates of larvae are very low and the survival rate of pupae is zero in winter months*." These authors also stated that they found that Qff could produce two to three generations annually but only at a low population level. However, they concluded that up to four generations per year and "relatively high" population densities could be achieved under the milder conditions in northern Victoria.

Due to the occurrence of small, isolated Qff outbreaks in Victoria since the late 1940s several State Government run activities were set up to reduce the incidence of outbreaks, ensure that these outbreaks were cleared up rapidly and attempt to reduce the incursion of Qff into the State.

In his review of Qff in Victoria, Kinsella (1983) stated that, in the early days of State Government control of Qff, when a Qff outbreak occurred, the Victorian State Government carried out the stripping of all fruit fly susceptible fruit within a 400m radius of the outbreak site following up with spraying gardens within a one mile radius from the outbreak with DDT. The ground beneath infested fruiting plants was also drenched with DDT.

Victorian Government regulations were set up to regulate the entry, into Victoria, of commercial fruits and vegetables that may be host to Qff from other States/ regions where fruit fly presence has been proclaimed. These regulations were enacted under the Vegetation and Vine Diseases Act (1958). Roadblocks were set up by the Victorian Government at border crossings from NSW at times when there were outbreaks in southern NSW (for example see the *Argus*, 1934; *Weekly Times*, 1934;). Also, regulations required that State Government inspectors must be informed of fruit being exported into Victoria and that such fruit was to be inspected to ensure freedom from pest fruit flies (for example see the *Age*, 1949). Such fruit could only enter Victoria through regulated entry points: Ports of Melbourne and Geelong, border towns of Albury, Gooramadda, Wahgunya, Mulwala, Cobram, Tocumwal, Echuca, Servicetown and other places that may be approved by the Minister (*Gosford Times and Wyong District Advocate*, 1934) at which places the fruit must be inspected. The number of roadblocks was reduced in 1959 to cover Albury, Wodonga, Echuca, Mildura, Bordertown, Mount Gambier (Victoria Government Gazette, June 19, 1959).

An internal roadblock was then set up at Bairnsdale at the border between East Gippsland, where the presence of Qff was proclaimed officially, and the rest of Victoria.

The effectiveness of roadblocks was reviewed in Victoria and, citing that the NSW Government ceased contributing towards roadblocks in 1982, "*there is no* *justification for retaining roadblocks as part of the fruit fly control measures*" (Kinsella, 1983).

For more details on Victorian roadblocks for fruit fly control see *Review of fruit fly Control in Victoria*, Department of Food and Agriculture, Quarantine & Inspection Services, May, 1992.

Kalang (2008) mentions the following with regards to various measures set up in response to the buildup of fruit flies in South East Austeralia. *In response to various fruit fly outbreaks in the Murrumbidgee Irrigation Area (MIA), Sunraysia, metropolitan Adelaide and Perth during the 1980s the Horticulture Policy Council (HPC, 1991) commissioned a report (subsequently known as the Bateman Report) on the impact of fruit fly on Australian horticulture.*

The Bateman Report recommended the establishment of fruit fly free areas and strategies for the management of fruit fly outbreaks, to reduce management costs to both government and industry. The establishment of the Tri-State Fruit Fly Strategy and the FFEZ (Fruit Fly Exclusion Zone) was endorsed by government in October 1994 and an MOU, formally establishing the Strategy, was signed in August 1996.

The Bateman report proved to be the catalyst for organised fruit fly management in South Australia, New South Wales and Victoria. Technical recommendations within the report underpinned policy for routine surveillance, reporting, corrective action and market access protocols which are both nationally and internationally accepted.

This document was called the Code of Practice for the Management of Queensland Fruit Fly (COP) (SCARM, 1996). The COP has been modified since 1996 and is still being reviewed.

Kalang (2008) adds: "*The FFEZ has remained vitally important for market access to all industries located within the zone, particularly those with access to lucrative international markets. Citrus, table grapes and summerfruit are the main crops of economic significance grown within this production region.*

Establishment of the Greater Sunraysia PFA. The level of importance of the Greater Sunraysia region to industry is highlighted by the recently implemented (2006) Greater Sunraysia Fruit Fly PFA project. The project is a cooperative effort by Victorian, NSW and Commonwealth Departments of Agriculture, and the three key horticultural industries within Sunraysia; citrus, summerfruit and table grapes."

See the Review of Fruit Fly Management in Victoria and Options for Future Management, Kalang Consultancy Services Pty Ltd, November 2008, for more detailed information on the history of fruit fly management in this period.

O'Loughlin's interpretations on the potential for Qff to survive and reproduce in Victoria (O'Loughlin, 1984) came true. Since around 2011/2012, Qff populations became very widespread around northern and eastern Victoria to such an extent that they have become established. That is, Qff can survive over winter in numbers sufficient to re-infest spring and summer host fruits. In 2012, because of the unprecedented explosion of Qff outbreaks, their widespread nature and the costs involved to manage these outbreaks, the Victorian and NSW Governments reduced their fruit fly tax-payer funded control activities and commenced cost-sharing arrangements between the State Governments, affected industry and the community.

Queensland fruit fly in and around COBRAM, Victoria

The following information was written by Charlotte Brunt, Cherry Growers Australia and A Jessup, Janren Consulting Pty Ltd.

Cobram/Yarroweyah

Cobram and Yarroweyah are adjacent rural towns in the Murray Goulburn irrigation district close to the Victorian/NSW border, approximately 260km from Melbourne. Historically, the area was pastoral, but it is now surrounded by orchards, dairy farms and wineries. Both towns are part of the Shire of Moira at an elevation of approximately 114-120m. Cobram has a population of approximately 6018, Yarroweyah 528.

Cherry harvest occurs between 1 November and 20 December.

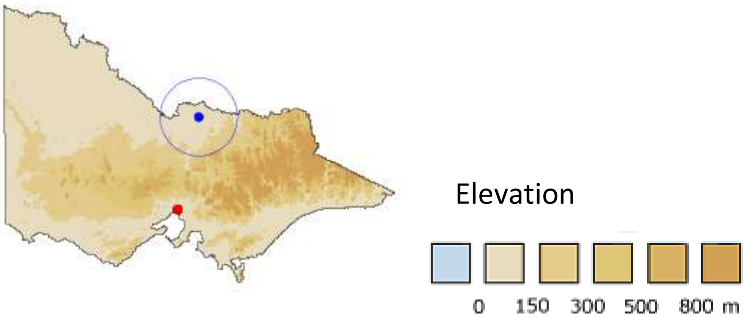

Figure 1: Location of Cobram and Yarroweyah in Victoria (BOM accessed 15/5/16)

Climate

The area is generally considered to have hot dry summers and cool wet winters. Annual rainfall for the region is 460mm, annual mean maximum temperature is 22.8˚C, and annual mean minimum temperature is 9.6˚C. In general, there are around 9 days per year recording minimum temperatures of 0˚C or less.

The closest weather station is at Tocumwal airport (NSW). It is 11km from Cobram and 13km from Yarroweyah. Average annual maximum and minimum temperatures are shown in Figure 1.

Possible sources of infestation

Cobram and Yarroweyah have an established fruit fly population. With approximately 4-5 generations per year this area is considered a suitable fruit fly habitat.

Abandoned orchards, unharvested crops, fruit movement and backyard trees in the township are potential infestation sites.

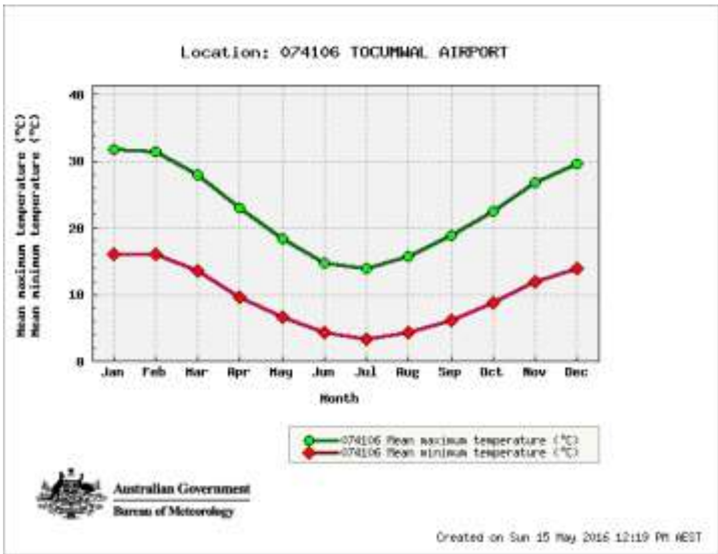

Figure 1: BOM Tocumwal airport data (1970-2016)

Fruit fly degree day model comparison

Single Triangle Model Results – 404DD –Cobram – OVIPOSITION DATES

- 404 DD ex Gen 0 which has an additional 66DD for egg maturation
- Degree day data for 2016 finished on the 15 May.
- Sunset temperature of 15˚C (the lower temperature threshold, and usual time of day, for Qff mating) typically occurs sporadically in late September and consistently in October. Sunset temperature may delay mating by one to five days, but was not limiting in 2015/2016. The limiting effect of sunset temperature is not accounted for in this model.

Oviposition occurs a week after sexual maturity is reached. Predictions indicate that the first generation of female flies are ready to oviposit two to three weeks after the commencement of harvest and that flies of the second generation commence oviposition after completion of harvest.
A seasonal window may be possible if active management occurs to reduce the number of flies overwintering, which would reduce fly numbers early in the season. Under these conditions, the second generation is likely to be damaging one.

Sunset temperature was not found to be limiting in the 2015/2016 season. Historical data averages suggested that it could delay mating by up to 5 days when the climate was cooler and may be applicable in cooler than average years.

Most models predict 4 generation in cool years and 5 generations in warmer years (e.g. 2015/2016). All models predict that the first generation has the potential to impact 2 to 3 weeks after cherry harvest commences. The second generation is ready to oviposit just after harvest is completed, making a seasonal window a viable option in Cobram if active management can keep numbers of the overwintering and first generation very low.

Data set	1990-2015	1990-1999	2000-2009	2010-2015	2015-2016
Upper & Lower development thresholds	11.5˚C, 36˚C	11.5˚C, 36˚C	11.5˚C, 36˚C	11.5˚C, 36˚C	11.5˚C, 36˚C
Gen 1	30 Nov	6 Dec	27 Nov	27 Nov	14 Nov
Gen 2	7 Jan	13 Jan	3 Jan	4 Jan	20 Dec
Gen 3	7 Feb	15 Feb	4 Feb	4 Feb	20 Jan
Gen 4	16 Mar	29 Mar	11 Mar	10 Mar	24 Feb
Gen 5	NO	NO	NO	NO	27 Mar
Gen 6	NO	NO	NO	NO	UK

Table 1: Predictions from three single triangle degree day models with varying thresholds and assumptions. 404 DD + 66 for Gen 0
UK = Unknown (if coloured green, unlikely)

Summary

The data show that the climate is becoming warmer and fruit fly generations are emerging earlier. On average, 4 to 5 generations are expected in the current climate and Cobram is classified as suitable for fruit fly.

The first generation is predicted to oviposit in the middle of November, but flies are not seen until the 19th to 25th of November. The second generation is ready to oviposit after harvest. Through careful management which target the overwintering population and first generation, fruit fly numbers can be kept very low over the production period.

If a seasonal window were to be pursued in Cobram, active management would be required to suppress populations. Growers would need to carefully consider the relative cost of management versus the risk. With these caveats in place, a seasonal window for market access may be possible for cherry growers in Cobram.

7. STERILE INSECT TECHNIQUE PROGRAMS

The Bateman Report (HPC, 1991) was also instrumental in the re-commencement of studies on improving the efficacy of, and putting into practice, the sterile insect technique (SIT) against Qff.

Insects are laboratory bred in large numbers then sterilised by gamma irradiation or low energy X irradiation and released into areas infested with wild populations. Initial releases are timed to slightly precede the commencement of seasonal outbreaks of wild insects. Periodic (generally weekly) releases ensure young and viable sterile insects are on hand at all times to intercept newly emerged wild adult fruit flies.

The sterile insect release method relies on the release of enough sterile insects to flood the existing wild population thus out-competing fertile insects in mating. If the ratio of sterile to fertile insects is high enough matings between fertile insects cease leading to the eventual eradication of the insect from the targeted area. If quarantine restrictions are efficiently enforced in that area then the insect disappears, otherwise a regular program of releases of sterile insects is necessary.

Basic research on the sterilisation, competitiveness and dispersal of gamma sterilised Queensland fruit fly commenced in Australia in 1975. A successful eradication campaign against Queensland fruit fly concluded in Western Australia in 1990. SIT has been used routinely against outbreaks of Queensland fruit fly and Mediterranean fruit fly in South Australia since 1986 to the present.

SIT Success stories

Successful SIT programs have been conducted in several countries.

- *Melon fly, Japan*

The melon fly was eradicated from the island Rota in the Marianas group in the Pacific Ocean in 1962-63 and then from Kume Island in Japan in 1976.

- *Oriental fruit fly, Guam*

The oriental fruit fly was eradicated from Guam in 1963.

- *Tsetse fly, Zanzibar and other parts of Africa*

The control and/or eradication of tsetse fly in some southern African countries commenced soon after. Fruit fly control/eradication programs are also currently underway.

- *New world screwworm fly, Texas, Curacao and Florida*

eradication of screw-worm fly from cattle production areas of Texas, USA in 1955

- *Mediterranean fruit fly, Mexico*

The Mediterranean fruit fly was eradicated from northern Mexico in 2014.

- *Mediterranean fruit fly, Dominican Republic*
- *Mediterranean fruit fly, other countries*

Successful SIT programs against Mediterranean fruit fly started in Western Australia in 1981, Mexico in 1972, Tunisia in 1974 as well as in Italy, Spain, Nicaragua, Hawaii, Peru and Israel.

- *Painted apple moth, New Zealand*
- *False codling moth, South Africa*

SIT in Australia: Mediterranean fruit fly

Between 1980 and 1984 Mediterranean fruit fly was eradicated from a 25 km^2 area of Carnarvon in Western Australia about 1,000 km north of Perth. Subsequent reincursions were eradicated but, without funding for maintenance of fruit fly freedom, Mediterranean fruit fly became re-established in Carnarvon in 1991. There are calls from growers and exporters to mount a campaign for the complete eradication of Mediterranean fruit fly from Australia using a combination lure trapping, bait spray, volunteer host removal and sterile insect release technique program.

SIT in Australia: Queensland fruit fly in the Eastern States

The sterile insect release technique was first studied in Australia by Dr J. Monro and Dr A. W. Osborn in 1961 to 1964. Their fruit fly mass rearing methods were based on work carried out by Professor L. C. Birch of the University of Sydney in the 1940s.

Dr Monro and Dr Osborn collected wild flies from around Sydney in 1960 to 1961 and, with seasonal injections of more wild fruit flies, a laboratory colony of about 100,000 fruit flies was established. This laboratory colony was used as the basis of their research and development of a sterile insect release system of production, packaging, sterilisation, despatch and release of sterile fruit flies.

These scientists developed the General Principles of Economic Mass-rearing for fruit flies. This entailed the management of the mother colony from which eggs for sterile insect production are collected and the efficient handling of fruit fly larvae during production so that a fruit fly factory for sterile insect release production can be run economically. They also pointed to the need for the development of more efficiencies in production.

Dr H. G. Andrewartha and his colleagues carried out sterile insect release studies in several central New South Wales towns from 1964 to 1965.

SIT in Victoria

From 1983 to 1984 sterile Qff, originally bred in Queensland by the Qld Department of Primary Industries, were released in Wangaratta for ecology trials. The purpose of the trial was to determine whether Qff would disseminate from an infestation under Victorian weather conditions and environment. The aim was to release marked sterile fruit flies at the centre of Wangaratta City to ascertain:

1. Whether Qff would readily disseminate from a regional centre.
2. Whether Qff would travel greater than 25 kilometres across open pastures or though eucalypt forests.
3. Whether Qff would travel greater than 25 kilometres along an inland watercourse (Ovens River).

A total of almost 1.5 million sterile Qff (50% male, 50% female flies) were release at Wangaratta in three releases. The majority of sterile flies tended to travel no more than one or two kilometres although some individuals did travel up to 7 to 13km. They tended to travel along water courses within lush evergreen foliage. They were trapped more heavily in times of calm, mild weather as opposed to windy or hot or cold weather (McWaters, 1984).

A fourth release, using flies reared at Burnley, Victoria, was reported on and a sterile fly was found to have flown 94km from the release site in Wangaratta (MacFarlane, 1987). There is some debate as to how true this is as it has been suggested that this fly may have "hitchhiked" the 94km inside a vehicle (Hill, 2011).

From May, 1989, Andrew Jessup from New South Wales Agriculture's Fruit Fly Laboratory at Gosford and Rob East and Norm Jones of the Victorian Department of Agriculture worked together in a sterile insect release program in and around Wodonga in Northern Victoria. Basing their work on that of Dr Monro and Dr Osborn and on that of the Western Australia Department of Agriculture, Mr Jessup and his colleagues at Gosford developed the production, temperature management, packaging and despatch system currently in use at the Fruit Fly Factory at Menangle, NSW.

In 1989 to 1990 sterile Qff were released in Wangaratta, Wodonga, Beechworth, Mt. Beauty, Bellbridge, Rutherglen, Yarrawonga, Cobram and Echuca. These flies were reared at the NSW Department of Agriculture facility in West Gosford, NSW. Over 14.5 million sterile Qff pupae were received by Victoria from 21 September 1989 to 19 April 1990. There were many problems in producing and transporting these flies and much was learned about the SIT program process.

Since then SIT has been tested or used against Qff in many parts of north eastern Victoria. The table below shows a resume of these projects. All sterile flies for these programs were produced by technicians in NSW Department of Primary Industries.

Category	Location	Season	Start Date	Duration (weeks)	# Flies Released	# Flies Captured	Recapture %
Major	Beechworth	2009-2010	22MAR10	5.1	2,604,000	98	0.0038
		2010-2011	08SEP10	4.7	1,392,000	7	0.0005
	Cobram	2003-2004	12JAN04	20.0	870,000	14,565	1.6741
		2004-2005	15DEC04	22.9	2,370,000	3,738	0.1577
		2005-2006	14DEC05	25.1	2,106,000	2,971	0.1411
		2010-2011	09NOV10	4.9	4,656,000	356	0.0076
	Echuca	2003-2004	27JAN04	19.4	432,000	1,494	0.3458
		2004-2005	21DEC04	21.9	2,346,000	799	0.0341
		2005-2006	15DEC05	23.7	1,680,000	414	0.0246
	Glenrowan	2010-2011	25OCT10	6.1	2,472,000	5,036	0.2037
	Melbourne	2009-2010	22SEP09	9.9	7,570,000	1,519	0.0201
	Yarrawonga	2003-2004	02FEB04	17.0	360,000	3	0.0008
		2004-2005	14DEC04	23.1	2,004,000	0	0.0000
		2005-2006	21DEC05	24.0	1,254,000	114	0.0091
		2008-2010	23FEB09	36.0	32,508,000	16,124	0.0496
Minor	Eldorado	2010-2011	26OCT10	13.0	1,968,000	5,830	0.2962
	Everton	2010-2011	26OCT10	13.0	1,212,000	3,742	0.3087
	Thoona	2009-2010	14MAY10	0.0	48,000	0	0.0000
		2010-2011	25OCT10	3.1	1,272,000	0	0.0000
	Wangandary	2009-2010	14MAY10	0.0	48,000	0	0.0000
		2010-2011	25OCT10	3.1	1,184,000	810	0.0684

Table 1. Summary of SIT projects in Victoria from 2002 to 2013 (from Fanson, 2013).

8. PEST MANAGEMENT: *Suggested fruit fly action plan*

ACTIONS:

- Apply protein baits to crop boundaries, untended fruiting trees, and crop trees early in the season, even before fruits mature to reduce the fruit fly load in and near your orchards. Follow label directions and cautions.
- Commence placement of fruit fly traps and male annihilation blocks around and within orchards. Maintain throughout the year. Follow label directions and cautions.
- Learn the differences between pest and non-pest fruit fly species caught in traps.
- Check for untended early fruit crops such as apricots and loquats and treat the trees and fruits with chemicals (following label directions and cautions), grubbing-out or fruit-stripping and destruction.
- Evaluate the benefits or otherwise of exclusion netting / covers.

ACTION THRESHOLDS FOR QUEENSLAND FRUIT FLY CONTROL

ACTIONS: ***Prior to fruit set***

- Check for the presence of apples or quince fruit hanging on into winter and remove trees or strip and destroy fruit.
- If there are house trees or feral trees which are untended and drop fruit late in autumn (e.g. plums, guavas, feijoas) there may be pupae surviving in the soil beneath or there may be adults in surrounding broadleaf evergreens (e.g. citrus).

Remove these trees, or pick up, strip and destroy unwanted fruit, run poultry under them or apply pesticide cover sprays (following label directions and cautions).
- Check for untended plants that fruit in early spring, especially loquats and apricots and treat as above.

ACTIONS: ***After fruit set and prior to harvest***
- Keep an eye on the numbers of pest fruit flies caught in traps. Identify the pest species and decide on how many pest fruit flies in traps will trigger action.
- Set up a list of anti fruit fly activities based on trapped fly numbers.
- Apply cover sprays following approved label directions, and repeat applications also following approved label directions.
- If there are low numbers of flies in traps and the crop is some way off ripening bait sprays might replace cover sprays and so pull the fruit fly population down prior to harvest.
- If you are registered under an Interstate Certification Assurance scheme (ICA) you must adhere to its requirements.

ACTIONS: ***After completion of harvest***
- Harvest or pick up and destroy fallen fruit, or unharvested fruit still hanging.
- Consider perimeter bait spraying and MATs.

PEST MANAGEMENT OPTIONS:
NOTE: The following information is a simple list of options. Some may apply to the situation while others may not be cost-effective. Please ensure that any use of chemicals has legislative approval for use under specified requirements displayed on the product label: target pest, host crop, State or Territory, impact on trade, whether for commercial or home garden use, health and environment.

- Fruit fly traps (including lures and pesticides used in them), male- or female-specific
- Fruit fly male annihilation pads, blocks or similar (including lures and pesticides used in them)
- Baits (usually a mixture of a protein source, as an attractant, with a pesticide)
- Chemical cover sprays (some are approved for use in home gardens and organic production areas)
- Repellents (not many on the market except a garlic-based spray). Some success has been reported with undersowing of aromatic plants e.g. wormwood.
- Netting – of individual fruit, fruit bunches, branches and whole trees or orchards
- Biological control – running chickens, guinea fowl, ducks, etc will reduce pest pressure over the coming seasons. Parasitic insects are not yet used commercially but may be available in the future. Sterile insect release is being investigated currently.

- Light, ultra violet light traps (e.g. “bug-zappers”) – some success has been reported by a grower in Howlong for use in igloo-style greenhouse production of susceptible vegetables.

9. PROJECT ACTIVITIES

BUREAU OF METEOROLOGY DATA

Daily weather data for Bureau of Meteorology (BOM) weather stations nearby to Cobram have been collected. Generally, these data date back many decades but the date of data collection commencement varies with each BOM station. Data exist for every BOM weather station in Australia. Some data go back more than 100 years.

There is little doubt that yearly temperature profiles have changed over the decades resulting in warming. Such warming favours the spread and local establishment of Qff. The other favourable factor that needs to be considered, along with warming, is Qff’s ability to adapt to new climatic and host conditions.

Other considerations include the fact that BOM data are records from just one site in the district being monitored. There is considerable variation in temperatures throughout a district: town areas vs open orchards, hard surfaces (roads, roofs) vs green space, etc. Fruit flies, if in sufficiently high numbers and temperatures are not deadly cold or hot, will survive by moving along favourable climatic or host-related gradients to shelter.

NOTE: BOM data, statistical analyses, degree-day calculations are available from the author.

CHERRY MODELLING DATA

Research carried out in 2015/2016 for Cherry Growers Australia compared BOM data mentioned above with known biological activity thresholds for Qff, such as threshold temperatures for egg hatch, larval development, pupal duration, adult maturity, etc to form a “fruit fly proliferation model” for Qff. This was used to estimate dates of fruit fly first and second generations for several cherry growing locations in Australia, including Cobram.

This model uses the number of degree-days above certain threshold temperatures needed for the fruit fly to move from one maturity stage (e.g. egg maturity) to the next (e.g. egg hatch). We have set this model up for Cobram and found that two or three Qff generations per year are possible especially after early summer based on BOM temperature data. However, as the next sections show, temperatures vary and fruit fly host fruits vary in availability within this district causing variability in fruit fly occurrence.

See pages 15 - 17 for more detailed information.

LANDSAT 7 AND 8 THERMAL IMAGING DATA

Thermal images have been collected for Cobram and surrounding region in an approximately 6km radius from Cobram Post Office. This area totals about 11,300Ha. These images date from 2013 to 2017 and will be used to assess sites within this region for comparative temperature variations.

These images show some of the thermal variability in Cobram town and areas within about 6km of the centre of Cobram. There are warm spots in town that would support overwintering fruit flies – as long as there are fruit fly hosts and suitable refuges nearby.

For more details refer to Appendix: MAPS SHOWING THERMAL IMAGES OF TARGET REGION DURING THE YEAR INCLUDING LIKELY QFF ACTIVITY.

SURVEY OF FERAL FRUITS NOT GROWING IN BACKYARD OR COMMERCIAL SITUATIONS

Roadside and channel-side fruiting plants, fruit growing in abandoned orchards, Council-planted fruiting street trees and non-tended rental properties may sustain sizable populations of Qff. A survey of roads in and around Cobram found a number of fruiting host plants for Qff. These include peaches, nectarines, Indian figs, olives, rose hips, figs, quinces and apples.

Samples of these fruit have been collected and stored over sand until any fruit fly eggs and larvae in those fruits have pupated. Pupae were then stored at ambient temperatures until adult eclosion. Adults insects were identified and recorded against fruit type.

VISITS

BAROOGA, COBRAM and KOONOOMOO

In March 2017 a survey of the urban areas of these towns was carried out looking at the presence of potential fruit fly host plants. This information will be correlated with BOM data, the fruit fly proliferation model, the Landsat images and the survey of feral fruits to evaluate the potential for winter fruit fly activity in these towns and the subsequent threat to spring/ summer crops in surrounding commercial orchards.

ORCHARDS OUT TO 6KM RADIUS

Orchards, feral fruit fly host plants and abandoned crops will be surveyed during the course of the project. Particular attention will be paid to crops that may influence the ability of Qff to overwinter (e.g. apples, quinces). Data from The Bureau of Meteorology, Google Maps, Landsat and the Goulburn Valley trapping grid will assist in assessing the overwintering potential of commercial and feral crops.

HOST MAPPING AND TEMPORAL MAPPING

Mapping of backyard, street and abandoned fruit trees in and around Cobram is currently underway. The types of host fruit found will be categorised into what time of year these fruit are ripening and, hence, able to be infested by Qff. This information are summarised in temporal maps. The two types of mapping will show where and when fruit fly host material is available for fruit fly infestation in and around Cobram. The aim, in his project, is to evaluate such occurrences for their Qff overwintering potential.

For more details refer to Tables 2 and 3 and Appendix: MAPS SHOWING LOCATIONS OF TRAPS, HOST PLANTS AND SIGNIFICANT TRAP CAPTURES.

Table 2. Ranking of fruit fly host infestation and timing risk

Colour code	Fruit ripening time	Infestation risk	Notes
	Early	Low	These fruit will be infested in late winter to early summer by flies that have overwintered. These fruit are the source of population expansion which often goes unnoticed.
	Early	Medium	
	Early	High	
	Mid-season	Low	These fruit serve as the hosts for second and subsequent populations of fruit flies and allow the population to expand rapidly. The weather at this time of year is generally very amenable to fruit fly survival.
	Mid-season	Medium	
	Mid-season	High	
	Late	Low	These fruit harbour eggs, larvae and pupae that may overwinter and commence infestation during the early part of the coming season. Adults, too, result from these fruit but they generally move to safe refuges away from host trees (except citrus).
	Late	Medium	
	Late	High	

Colour codes refer to results presented in Table 3 and Appendix: MAPS SHOWING LOCATIONS OF TRAPS, HOST PLANTS AND SIGNIFICANT TRAP CAPTURES

Table 3. Fruit fly host plants in and around Cobram, 2017 – Main harvest periods

Host	Colour code	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Avocado								■	■	■			
Blackberry					■	■	■						
Cherry				■	■	■							
Citrus Grapefruit												■	■
Citrus Kumquat			■	■	■								
Citrus Lemon						■	■	■	■	■	■		
Citrus Mandarin								■	■				
Citrus mixed		■	■	■	■	■	■	■	■	■	■	■	■
Citrus Orange winter		■	■								■	■	■
Citrus Orange summer				■	■	■	■	■	■	■			
Feijoa										■	■	■	
Fig									■	■	■		
Grape							■	■	■				
Indian fig								■	■	■			
Loquat		■	■										■
Medlar								■	■				
Mulberry		■	■	■									
Nut Chestnut Walnut Almond								■	■				
Olive											■	■	
Persimmon								■	■	■	■	■	
Pome Apple						■	■	■	■	■	■	■	
Pome Pear						■	■	■	■	■			
Pome Pear Asian					■	■	■						
Pomegranate								■	■	■	■		
Rose hip								■	■	■	■		
Stone Apricot			■	■									
Stone Peach Nectarine						■	■	■	■	■			
Stone Plum								■	■	■			
Stone Prunus street			■	■	■								
Tomato						■	■	■	■				

OVERWINTERING ASSESSMENTS

Infested ‘Pink Lady’ apples collected from the district have been placed in overwintering chambers placed in two commercial orchards and a backyard situation in Cobram. These chambers consist of a large plastic plant tub with drainage holes covered with mesh to stop Qff larvae from the apples escaping the chamber into the ground below. The apples were placed on a 15cm layer of potting mix to allow for pupation and shedding of rain water. The chamber was covered with mesh to allow aeration and to simulate actual orchard conditions as much as possible. A temperature data logger was also placed inside the chamber with the apples recording the temperature every hour.

Over the next few months eggs and larvae in these fruit will mature and develop into pupae and adult flies all of which will be retained inside the chamber. Assessments will be made on when larvae pupate and when adults eclose. The possibilities are:

i. Qff overwinter as immatures – i.e. Eggs and larvae remain inside the fruit during the winter, then pupate and eclose as adults in the spring
ii. Qff overwinter as pupae – either inside the fruit or in the soil beneath the fruit – i.e. Qff overwinter as pupae
iii. Qff adults emerge during winter – i.e. Qff overwinter as adults
iv. Combination of some or all the above – i.e. Qff individuals develop intermittently over winter, some develop quickly and others more slowly.

A similar cage, with temperature data loggers was set up at Bateau Bay, NSW, using a sample of infested 'Pink lady' apples (sourced as above) as a parallel, or replicate, trial.

Results:

Trials conducted within this project tested the survival of Qff eggs, larvae and pupae in infested Pink Lady apples sourced from Shepparton under Shepparton and Cobram winter temperatures compared with temperatures on the warmer Central Coast of NSW. Results showed that eggs, larvae and pupae survived in or near the apples when given Central Coast conditions (between 5˚C minimum and 20˚C maximum) where accumulated degree-days (ac DD) above the Qff temperature development threshold of 12.405˚C was 261DD between fruit collection and adult eclosion but perished under the winter conditions at both Shepparton (-1.3˚C to 19.8˚C, 112DD from fruit collection to the time adult flies emerged on the Central Coast) and Cobram (0.2˚C to 20˚C, 90DD).

These trials found that, in Shepparton and Cobram, Qff survives the winter as adults, not as eggs, larvae or pupae whereas, on the Central Coast of NSW eggs, larvae, pupae and adults can all survive the milder winter climate there.

The last date of infestation after which eggs, larvae and pupae perish due to the cold was estimated by working backwards by 261DD on Shepparton and Cobram temperatures. It was found that eggs, larvae and pupae from fruit infested prior to 16 to 20 April had sufficient warm days to allow adult emergence prior to the commencement of the lethal winter period. These adults may then overwinter in the Cobram region becoming the source of new infestations and population expansion in the following spring/ summer.

Qff eggs and larvae in fruit and pupae in soil after mid-April will not survive the winter being less tolerant of cold than adults.

Implications:

Even in the relatively mild winter climate of Bateau Bay, NSW, Qff adults emerge from their pupae after many more days at sub-optimal temperatures than at optimal temperatures of around 26˚C.

APPLES: Infested 'Pink lady' apples were picked off ground and off trees at Greenwood Orchards, Merrigum near Shepparton on 10 May 2017. Some fruit were stored in emergence chamber in Greenwood Orchard on 10 May 2017 and more were stored in two chambers at Uncle Charlie's at Cobram. Some more of these apples were stored in emergence chamber in Bateau Bay on 11 May 2017.

Pupae were sieved from the Bateau Bay apples on 15 May 2017 and the pupae left outside (in emergence chamber).

Bateau Bay pupae started emerging on 9 June 2017 with the main emergence between 17 June 2917 and 28 June 2017. Last adult eclosion from Bateau Bay apples occurred on 27 July 2017.

On 10 July 2017 emergence chambers in Greenwood Orchard and Cobram were checked but 0 adults had eclosed. Samples of pupae were brought back to Bateau Bay and stored near emergence chamber there.

Also on 10 July 2017 more apples were picked up off the ground from the Greenwood Orchard because there were live larvae found in the apples, on 10 July 2017, in the emergence chamber (NOTE that the chamber is impermeable to new infestations so larvae, then, were from infestations on or before 10 May 2017). These fruit were taken to Bateau Bay and put into emergence chamber there.

As of 22 August 2017, no adults had eclosed in Bateau Bay from the pupae sampled from the Greenwood Orchard and Cobram emergence chambers.

Also there was 0 pupation found under the apples collected from Greenwood Orchard on 10 July 2017 by 22 August 2017.

Other fruit collected around Cobram:

ORANGES collected from Grants Crt, Cobram on 21 March 2017 and brought back to Bateau Bay and stored outside in shed at ambient.
Pupae were collected from these fruit on 1 April 2017 then 11 April 2017 then 18 April 2017 then 24 April 2017 and then 10 May 2017 and stored at ambient.

Fly species	Fly activity	Collected 1 April 2017	Coll 11 Apr	Coll 18 April				Coll 24 Apr			
Dirioxa pornia	Adults emerged	peak emergence on 20/4/2017	Sent to Macq Uni	22-Apr	25-Apr	28-Apr	4-May	27-Apr	2-May	11-May	13-May
Qff			21-Apr	22-Apr	23-Apr	0	0	0	0	0	0

One Qff pupa was collected from Cobram oranges on 18 May 2017 but it did not eclose.
L. brouniana: Many metallic green tomato flies were reared from Cobram oranges, too.

MORE ORANGES were collected from Grants Crt, Cobram on 10 May 2017 and stored outside at ambient at Bateau Bay

Adult Qff emerged from these fruit on:			
1-Jun	8-Jun	10-Jun	11-Jun

INDIAN FIGS collected from Cobram on 21 March 2017 also produced Qff at a rate of about 2 to 3 pupae per fruit.

INTERPRETATIONS
Late infested apples that remain in Shepparton-Cobram area are not a source of new populations for that area. However, they would be if they occurred in Bateau Bay. HOWEVER, we need more information from later assessments of emergence chambers in Merrigum and Cobram due first week of September and first week of October 2017.

Oranges and Indian figs infested in late March may be more likely to produce overwintering adult flies than apples infested in May.

15 January 2017

- Shepparton, VIC – Peaches (only 2 Qff, but there were >1,200 metallic green tomato fly (*Lamprolonchaea brouniana*) found to be the main infesting pest.

15 to 17 February 2017-05-22

- Howlong, NSW – Apples, tomatoes (all infested with Qff)
- Yarrawonga, VIC – Tomatoes (infested with Qff)
- Gapsted, VIC – Apples, peaches, nectarines (all infested with Qff)

- Cobram, VIC – Oranges (infested with Qff)
- Rutherglen, VIC – Apples (infested with Qff)
- Near Rutherglen (Gooramadda Road), VIC – Figs (no Qff pupae found)
- Boohraman, VIC – Peaches (infested with Qff)

2 March 2017

- Merbein, VIC – Jujube (infested with Qff, pupae collected 8 March to 28 March 2017)

21 to 27 March 2017

- Cobram, VIC – Oranges (infested with Qff)
- Cobram, VIC – Indian figs (all infested with Qff, pupae collected from 28 March to 12 April 2017, >90% of pupae collected on 12 April were *Dirioxa pornia*).

10 to 13 May 2017

- Cobram, VIC – Oranges, Indian figs and rose hips (all, except rose hips, infested with Qff)
- Merrigum, VIC – Apples (all infested with Qff)
- Ardmona, VIC – Quinces (no pupae produced as of 24 August 2017)

30 November 2017

- Cobram, VIC – Oranges from Grant Crt (infested with Qff and *Dirioxa pornia*)
- Cobram, VIC – Loquats from Karook St (infested with Qff)

10. CONCLUSIONS

MAJOR FINDINGS

1. Queensland fruit fly (Qff) has survived winter in the Cobram region and surrounding Goulburn Murray Valley for at least each year since 2012 (Figures 1 and 2).
2. Qff is, however, unlikely to survive Cobram winters as eggs and larvae in fruit and as pupae in the soil. Degree-day modelling estimates that any Qff eggs and larvae in fruit and pupae in the soil later than mid-April are likely to die out due to cold temperatures in Cobram during the winter (based on 2017 temperatures – the cut-off date will vary depending on the severity of the previous winter). Refer to
3. Qff survive Cobram winters as adults.
4. Degree-day modelling has estimated that Qff eggs and larvae in fruit and pupae in the soil present earlier than mid-April are likely to mature to flying adults before winter sets in in the Cobram region. These adult flies will be the predominant overwintering generation.

5. There are warm spots in the Cobram region where, in winter, Qff adults may survive. These areas appear to be present in evergreen refuges close to open grassy areas such as sports ovals (Figures 4, 5 and 6).
6. Fruiting plants that are suitable for hosting Qff are present throughout the urban area of Cobram (Tables 1 and 2).
7. Suitable host fruits for Qff eggs and larvae are present in the urban area of Cobram throughout the year (Tables 1 and 2).
8. Qff trappings are associated with the presence of fruiting host trees, especially those that fruit mid- to late-season (i.e. from February to mid-April) (Figure 5).
9. Qff males trapped in September and October are likely to be those adults that overwintered in favourable positions, probably near their host fruiting plants (i.e. plants that fruit from February to mid-April – Tables 1 and 2), during the previous winter in Cobram.
10. Qff males trapped in late November/ early December are most likely to be the offspring of overwintered adults (i.e. the first generation of Qff post-winter). These are the insects that will be the most damaging to subsequent summer and autumn crops in the Cobram area.
11. Low trap capture rates during late October and November are due to the fact that most of the overwintered adults have died out. However, those insects have, if not controlled adequately, already mated and laid their eggs in fruit. These insects will be the first generation of Qff post-winter.
12. After December Qff populations overlap due to variations in temperature and host-plant availability across the Cobram area.
13. Trap captures will decline from about May as day and night temperatures decrease and males switch over from being attracted to para-pheromones in the traps to seeking proteinaceous foods and carbohydrates to survive low mobility regimes during the winter.
14. A brief survey of host plants in the urban area of Cobram in late November revealed the presence of live adult Qff ovipositing into ripe loquats and oranges. Samples of loquats (new season fruit) and oranges (late-hanging winter fruit) reared a large number of Qff larvae and pupae as a result. Resulting adults will be the start of the second generation of Qff post-winter. These adults will commence being trapped some time in January.

Conclusions

A package of activities giving managers the means to plan timely, cost-effective and successful control of Queensland fruit fly in the Cobram & District region.

Major components:

1. An understanding of Qff cold climate biology, associated degree-day models for Qff maturation and survival
2. Strategies for monitoring and controlling Qff populations - male and female traps, hygiene (fruit pick-up, host removal, effective disposal), planning baiting programs
3. Mapping Qff host plants, timing of fruit ripening
4. Mapping favourable Qff microclimates – potential overwintering sites
5. Overlaying trapping data, host fruit availability and warm microclimates - to pinpoint likely Qff post-winter hot spots to allow timely and accurate targeting

11. FUTURE WORK

1. Ensure orchard/ garden hygiene, especially around March and April to reduce overwintering populations of Qff adults.
2. Target Qff host plants in hot spot areas identified by host mapping.
3. Target loquats and late-hanging oranges to reduce first generation post-winter Qff adults.
4. If possible, start weekly baiting in commercial orchards at least 6 weeks before harvest, during harvest and weekly for at least three weeks after harvest to reduce impact at harvest and to reduce overwintering populations.
5. Set up and use Qff monitoring grids (i.e. male-targeting para-pheromone traps) with weekly (spring, summer and autumn) and fortnightly (winter) trap readings to check for Qff population build-up and locations of Qff population build-up.
6. Ensure data (including zero catch data) from trapping grid are recorded and kept as they will be used for future applications for Fruit Fly - Pest Free Area (PFA) or Fruit Fly – Area of Low Pest Prevalence (ALPP).
7. The trapping grid should be kept in place as long as there is a desire for PFA or ALPP approval.

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12. ACKNOWLEDGMENTS

Person	Affiliation	Role
Alexandra Tait	Moira Shire Council, Industry Development Officer (Economic Development)	Project manager
Celeste Brockwell	Moira Shire Council, Industry Development Officer (Economic Development)	Project manager
Ross Abberfield	Moira Shire Council (Safety, Amenity and Environment)	Regional Fruit Fly Coordinator
Lynton Greenwood	Greenwood Orchards, Merrigum	Farm business operator, location of Qff overwintering experiment
Board	Cobram & District Fruit Fly Group	Project oversite and source of information
Russell Fox	I.K. Caldwell Rural	Manager of Cobram & District Qff trapping grid
Charlie Fox	Home garden, Cobram	Location of Qff overwintering experiment
Richard Mapson	Department of Economic Development, Jobs, Transport and Resources (DEDJTR)	State Government liaison, Qff trapping

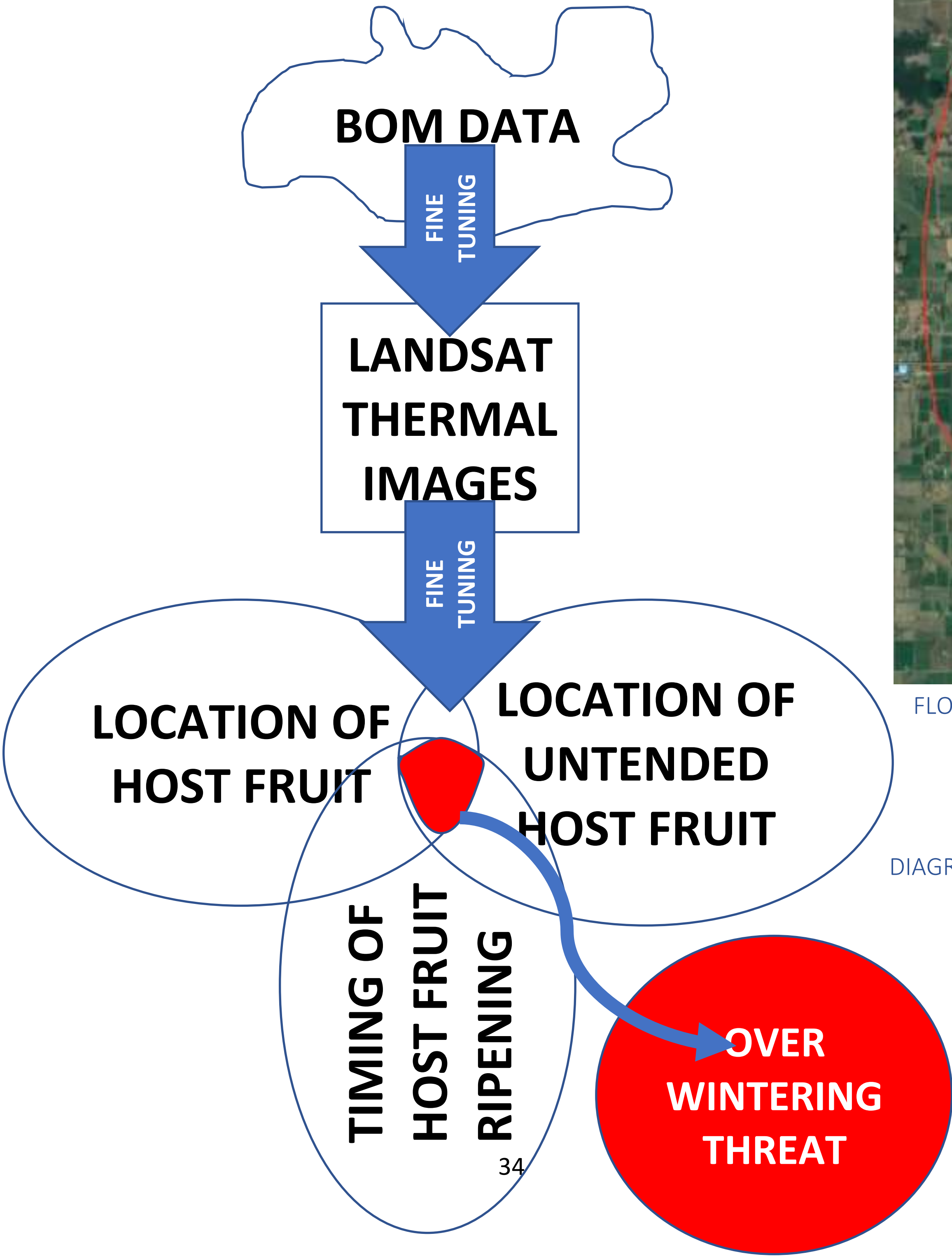
13. APPENDICES

Project target area

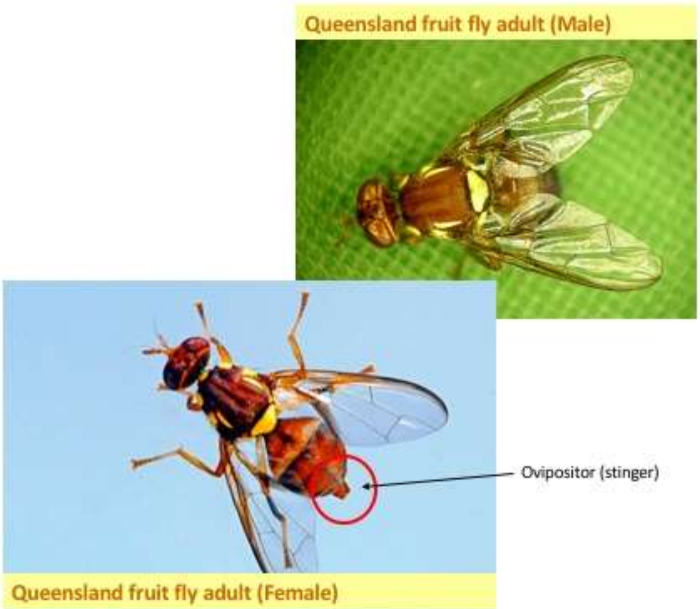
– an area within a 6km radius of Cobram Post Office

FLOW

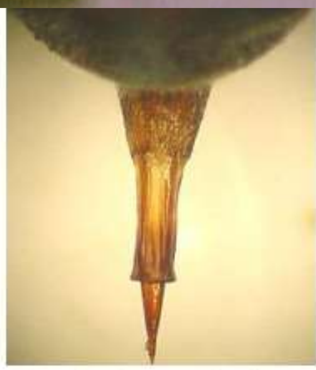
DIAGRAM



QFF LIFE CYCLE



Queensland fruit fly laying eggs into a wild fig



Female Queensland fruit fly's ovipositor ("stinger")

Left: Queensland fruit fly laying eggs into a cherry

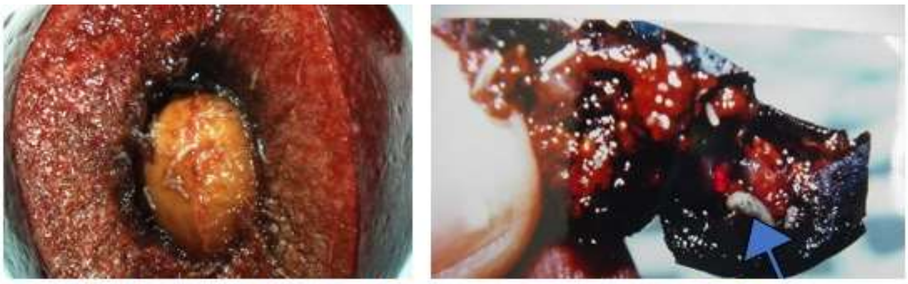
Fruit fly sting marks in nectarine (L.) and loquats (R.)

Fruit fly sting marks are not easily seen in blueberries (L.) and cherries (R.)

Eggs hatch within a minimum of 24 to 48 hours

Larvae grow in length from about 2mm (first larval instar [stage]), through 5mm (second larval instar) to 8 to 10mm (third larval instar) in fruit over a minimum of 7 days up to 40 days in cool weather and then jump out of the fruit.

Photos: Courtesy of NSW Dept of Primary Industries

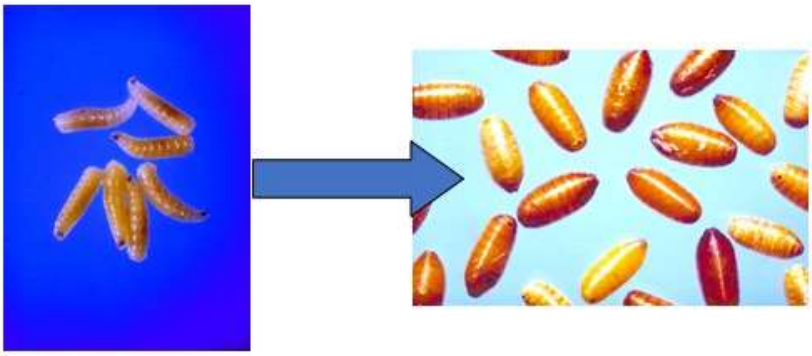


First and second instar larvae in a cherry (L.) and blueberry (R.)

Fruit fly damage in an orange (L.) and peach (R.)

Fruit fly damage (external) in an orange (L.) & peach (R.)

If Queensland fruit fly populations are high they will attack small, immature, green fruit such as these peaches from the Hunter Valley, NSW



Photos: Courtesy of NSW Dept of Primary Industries

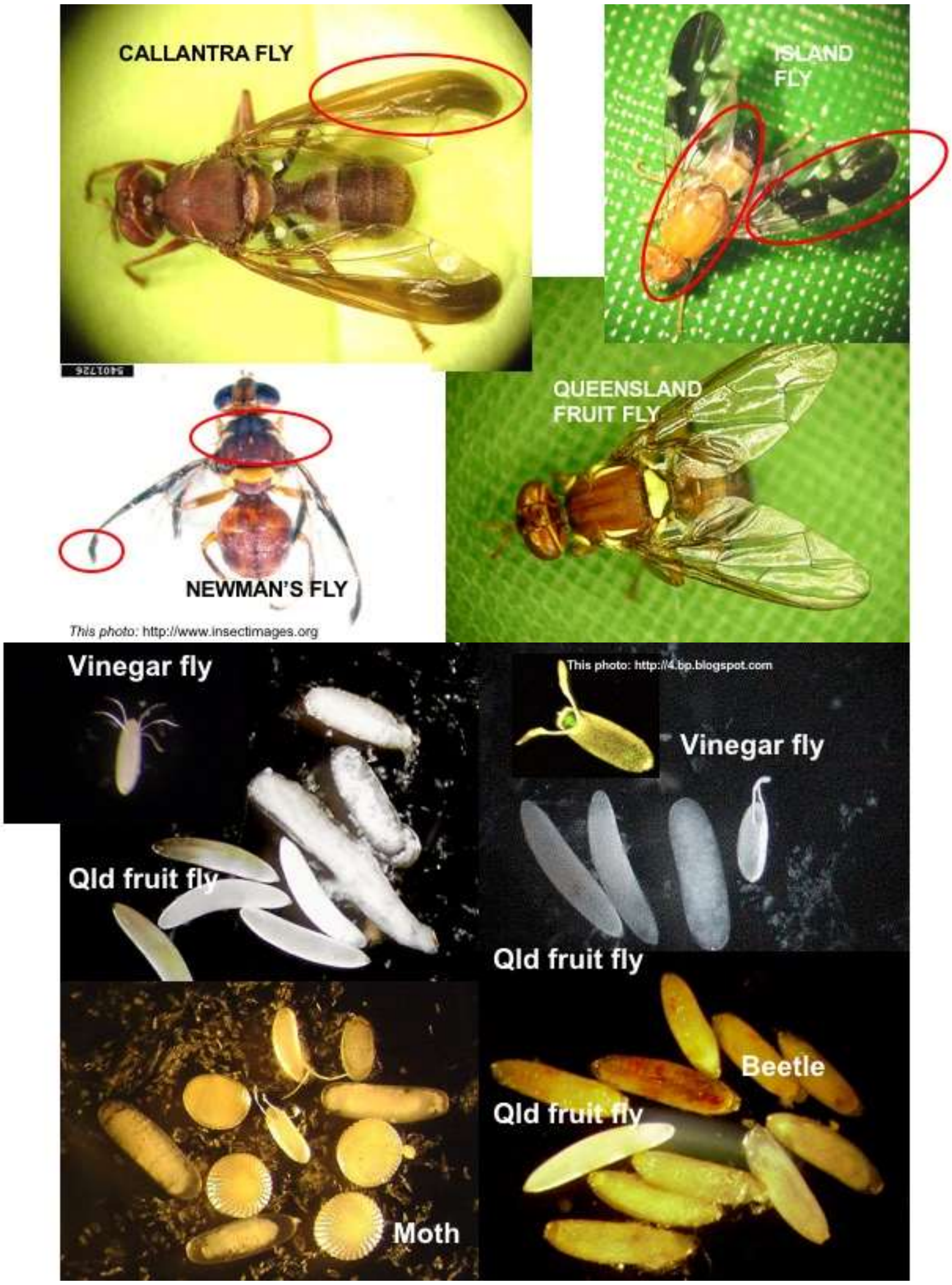
After leaving the fruit the larvae become pupae and stay in the ground or mummified fruit – for a minimum of 10 days up to about 20 days in cool weather

After a minimum of 10 days the adult fly emerges from the pupal case. It takes one to two weeks for the flies to mature, mate and lay more eggs.

- 1 generation takes 22 to about 70 days

Photo (left): Courtesy of NSW Dept of Primary Industries

FLIES THAT MAY BE CONFUSED WITH QFF




Qld fruit fly
Fruit fly
This photo: http://www.padil.gov.au
2 mm
This photo:
http://www.ifom-ieo-campus.it
Vinegar fly
Carpophilus
beetle
This photo: http://www.padil.gov.au
Metallic green
tomato fly
female
pupa
prepupa
Metallic green tomato fly
Island fly
fly

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MAPS SHOWING LOCATIONS OF TRAPS, HOST PLANTS AND SIGNIFICANT TRAP CAPTURES

Figure 1. Overall map of Cobram and Barooga (Koonoomoo and Yarroweyah are not included, here)

Colour code	Fruit ripening time	Infestation risk	Notes
	Early	Low	These fruit will be infested in late winter to early summer by flies that have overwintered. These fruit are the source of population expansion which often goes unnoticed.
	Early	Medium	
	Early	High	
	Mid-season	Low	These fruit serve as the hosts for second and subsequent populations of fruit flies and allow the population to expand rapidly. The weather at this time of year is generally very amenable to fruit fly survival.
	Mid-season	Medium	
	Mid-season	High	
	Late	Low	These fruit harbour eggs, larvae and pupae that may overwinter and commence infestation during the early part of the coming season. Adults, too, result from these fruit but they generally move to safe refuges away from host trees (except citrus).
	Late	Medium	
	Late	High	

Table 2. Key for fully coloured patches on the following maps indicating sites of Qld fruit fly host plants, the season in which they are susceptible to Qld fruit fly and their relative risk to being infested with Qld fruit fly

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Figure XX. Map showing K Caldwell and DEDJTR <u>RURAL</u> trap sites for Cobram, Cobram East, Koonoomoo and Yarroweyah.

Coloured circles indicate the position of traps which registered ≥1 fly/ trap/ week.

Green circle: ≥1 fly/ trap/ week during October 2017

Red circle: ≥1 fly/ trap/ week during November 2017

NOTE: Circles with purple FF symbol in centre denote positive DEDJTR traps. All others are K Calwell traps.

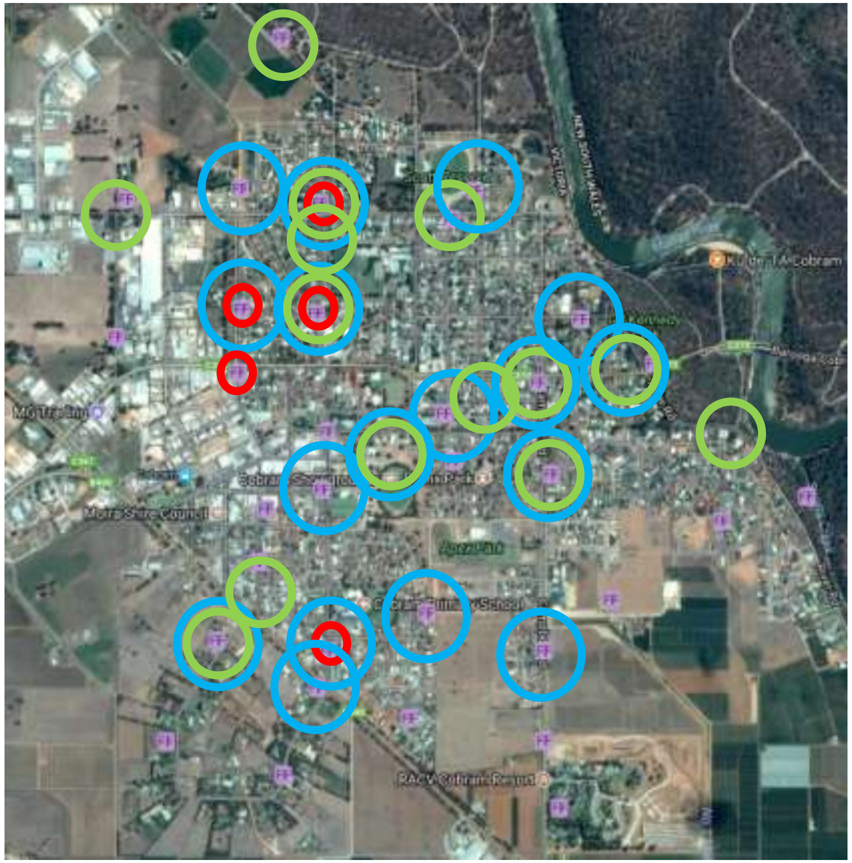

Figure XX. Map showing URBAN IK Caldwell and DEDJTR trap sites for Cobram, Cobram East, Koonoomoo and Yarroweyah.

Coloured circles indicate the position of traps which registered ≥1 fly/ trap/ week.

BLUE circle: ≥1 fly/ trap/ week during September 2017

GREEN circle: ≥1 fly/ trap/ week during October 2017

RED circle: ≥1 fly/ trap/ week during November 2017

NOTE: Circles with purple FF symbol in centre denote positive DEDJTR traps. All others are IK Calwell traps.

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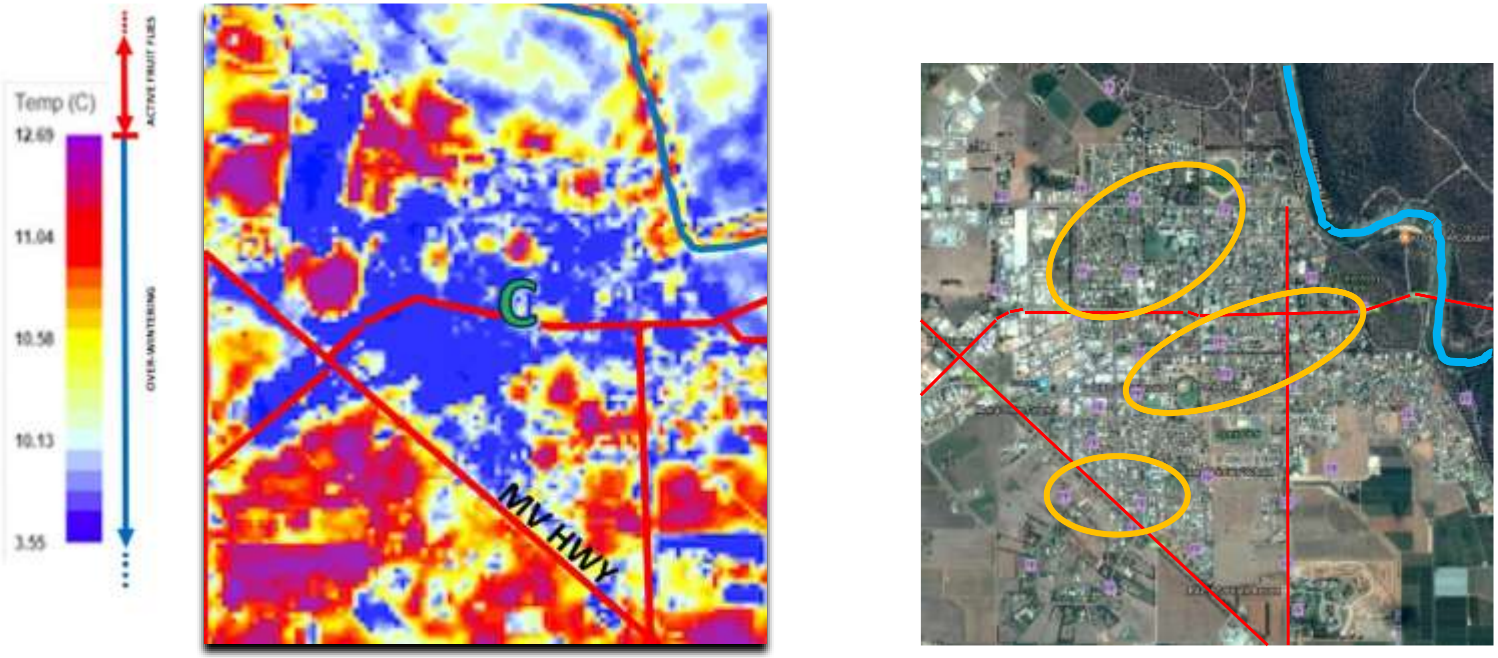

Thermal image (~1030h 27 May) of Cobram urban area with corresponding trap locations. Coloured ovals denote the September, October, November fruit fly "hot spots" for 2017

Figure 3. MAP OUTLINE FOR COBRAM QFF HOST FRUIT SURVEY. See following maps numbered 1 to 16 [COBRAM] for details of host plant locations (solid colour patches) and positive Qld fruit fly trap captures (colour circles)

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Figure 4. MAP OUTLINE FOR BAROOGA QFF HOST FRUIT SURVEY See following maps numbered 1 to 8 [BAROOGA] for details of host plant locations (solid colour patches) and positive Qld fruit fly trap captures (colour circles)

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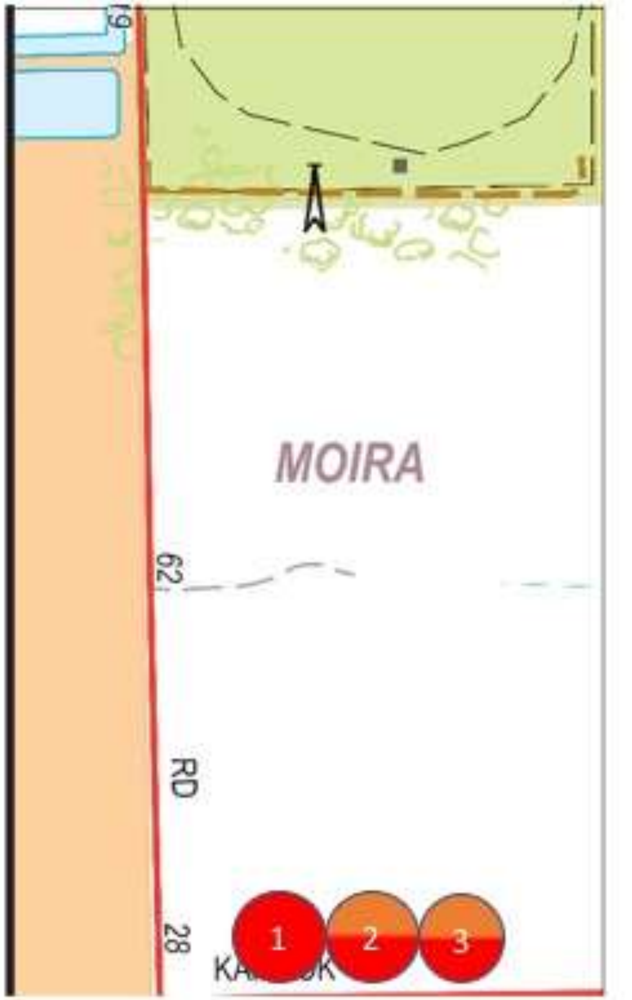

1. COBRAM

1. Plums (many trees)
2. Plums and many loquats
3. Figs, chestnuts, loquats, olives, stone fruit, many fruits

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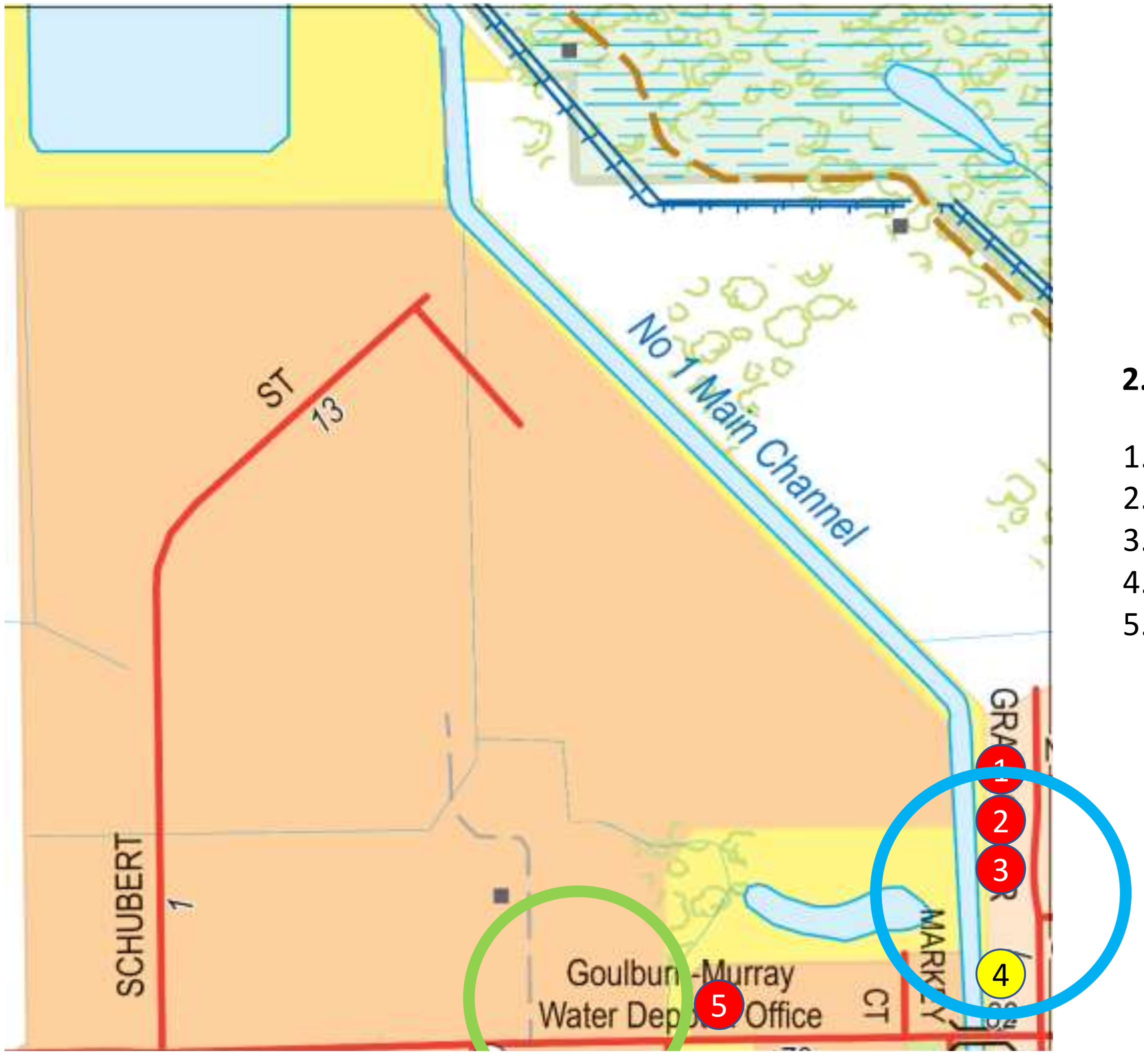
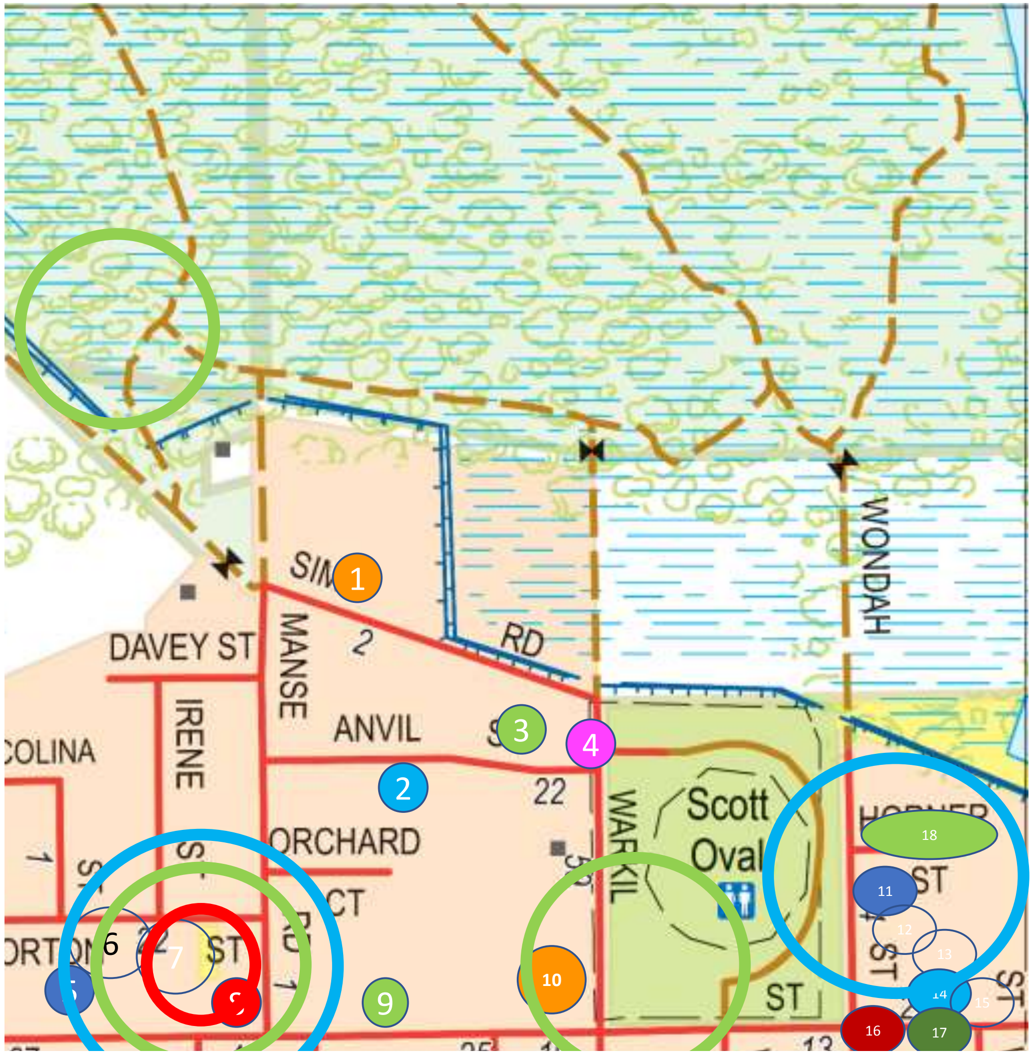


2. COBRAM

1. Feral peaches
2. Feral peaches
3. Feral peaches
4. Indian fig
5. Feral peaches



3. COBRAM

1. Loquat
2. Citrus (late)
3. Citrus
4. Cherry
5. Olive
6. Peaches, grapes, chestnuts, figs, cherries
7. Persimmons, apples
8. Peach
9. Citrus
10. Loquats
11. Olives
12. Olives, figs, peaches
13. Figs, apples
14. Apples
15. Apricot, figs, plums, citrus
16. Peach
17. Lemon
18. Asian pears as street trees

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4. COBRAM

1. Citrus (late)
2. Citrus (late)

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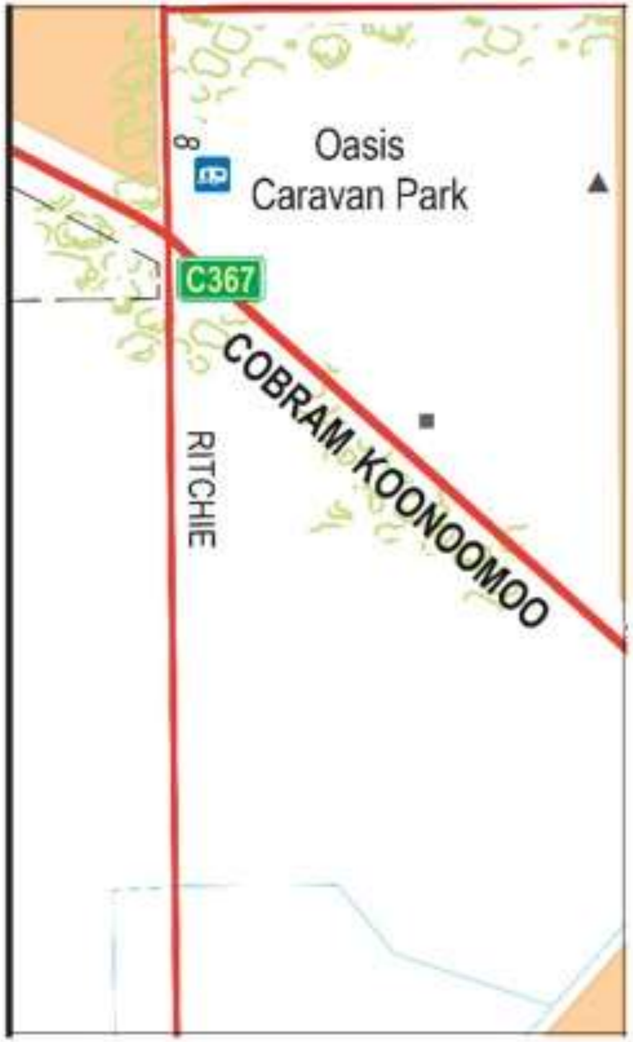

5. COBRAM

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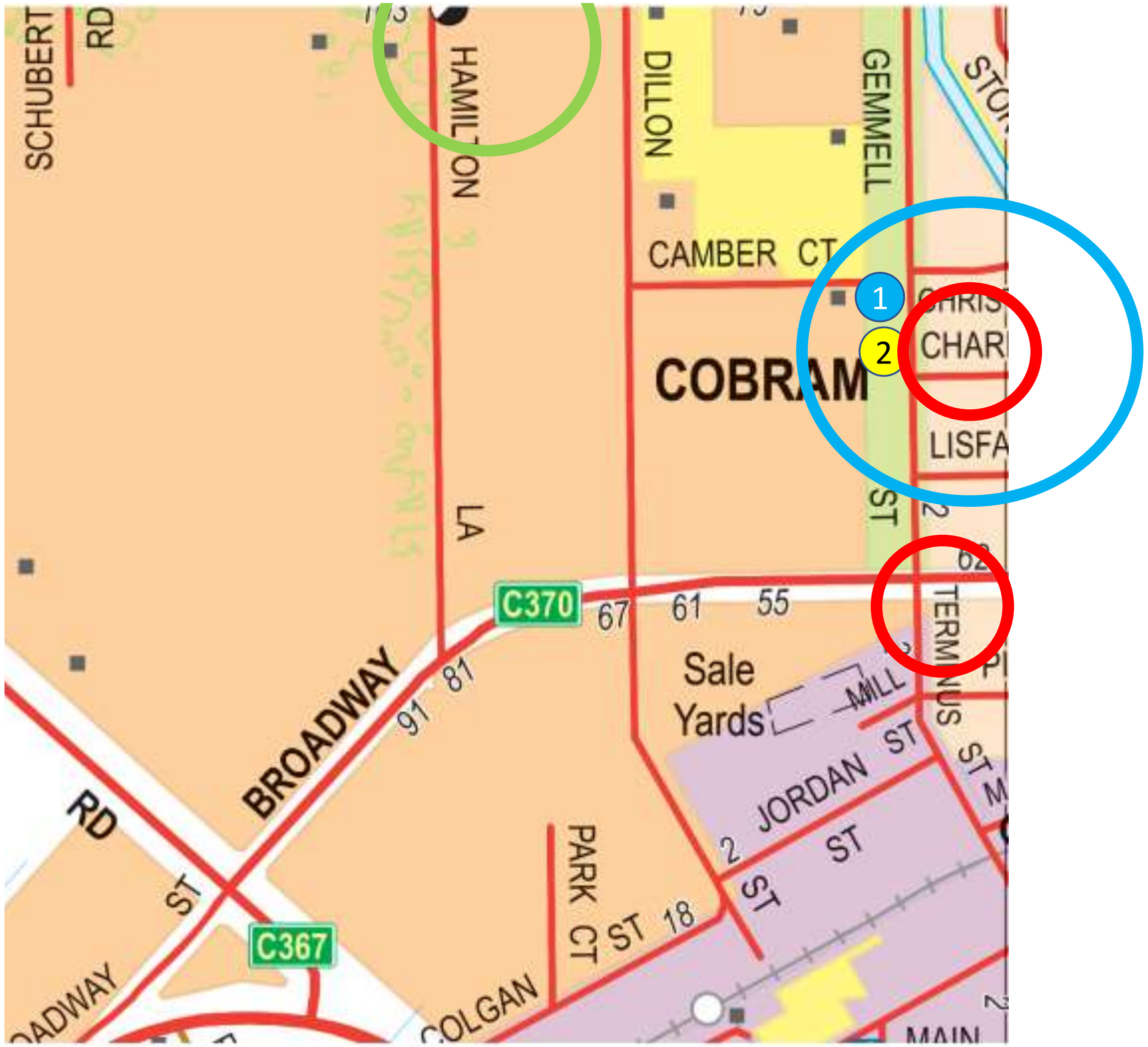

6. COBRAM

1. Apples
2. Indian figs

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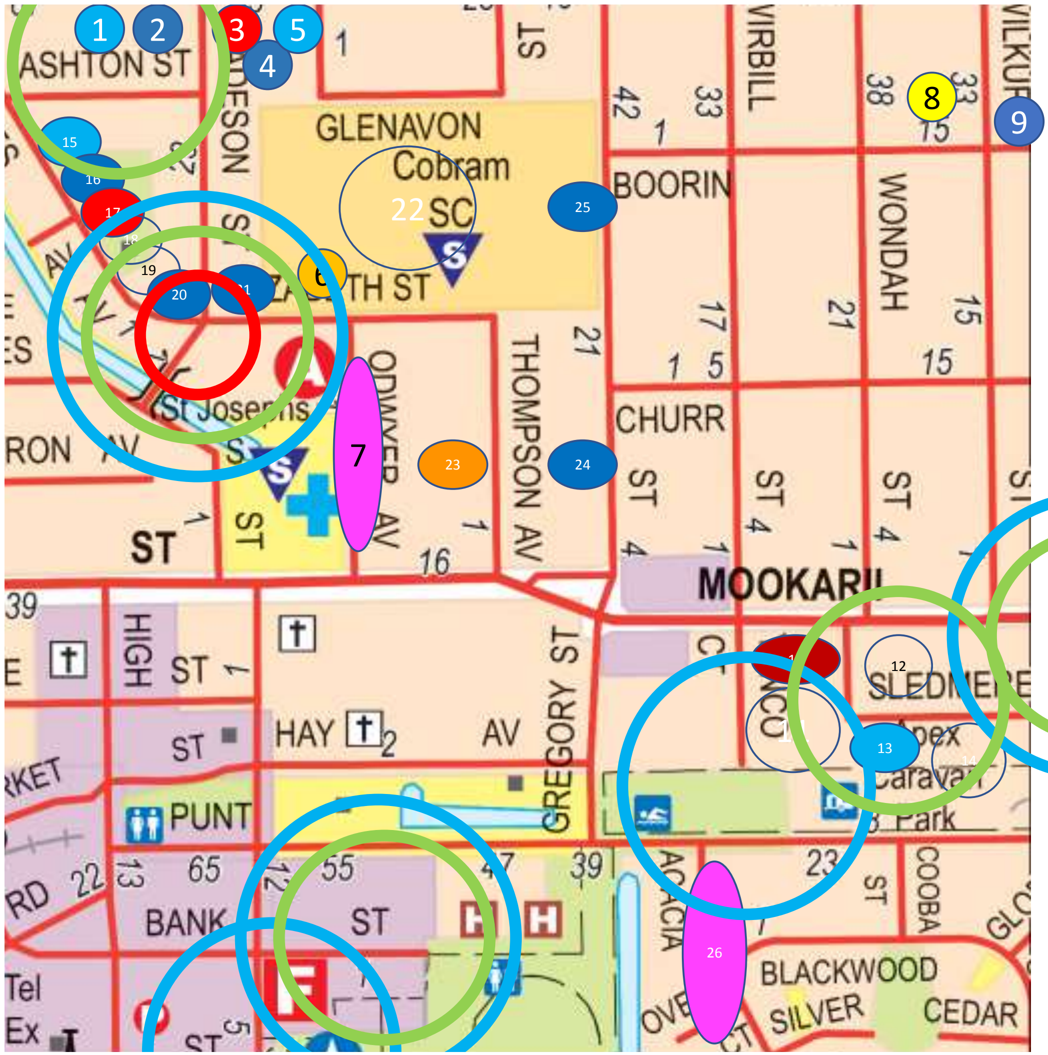
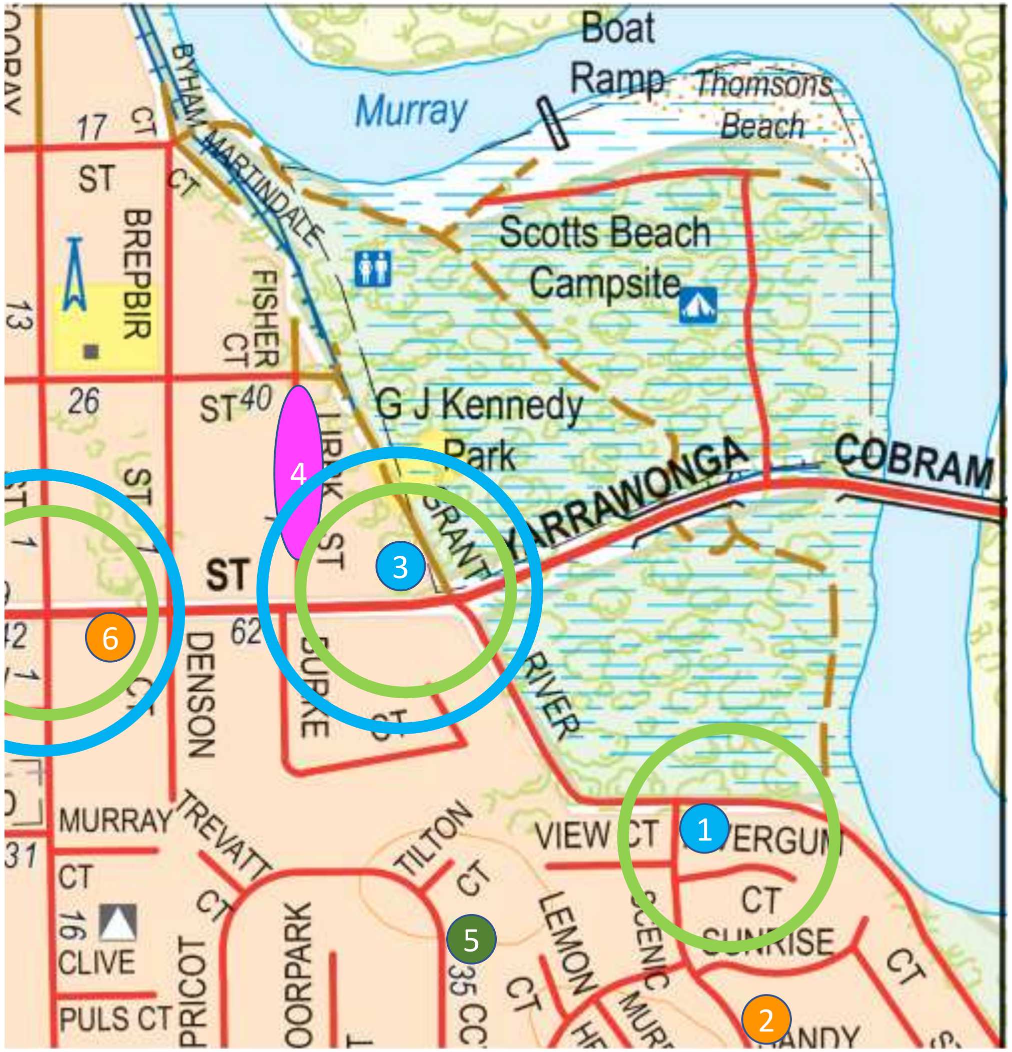


7. COBRAM

1. Apples and other fruit
2. Citrus
3. Peaches and plums
4. Citrus
5. Citrus (late)
6. Apricot
7. Prunus street trees
8. Fig
9. Lemon
10. Peach
11. Peaches, apples, lemon, lime, orange, finger lime, cumquat
12. Persimmons, figs, olives
13. Oranges (late)
14. Loquats, olives, citrus (late)
15. Citrus (late)
16. Olives
17. Plum
18. Citrus (late), peach
19. Figs, plum
20. Citrus
21. Citrus
22. Pioneer Park surrounded by house gardens with many plums, peaches, apricots, citrus, mulberry, kiwifruit
23. Loquat
24. Citrus
25. Citrus
26. Prunus street trees



8. COBRAM

1. Citrus (late)
2. Mulberry
3. Citrus (late) – abandoned
4. Prunus street trees
5. Mixed fruit trees under netting
6. Mulberry, crabapple

9. COBRAM

1. Cherries, figs, apples – small mixed orchard

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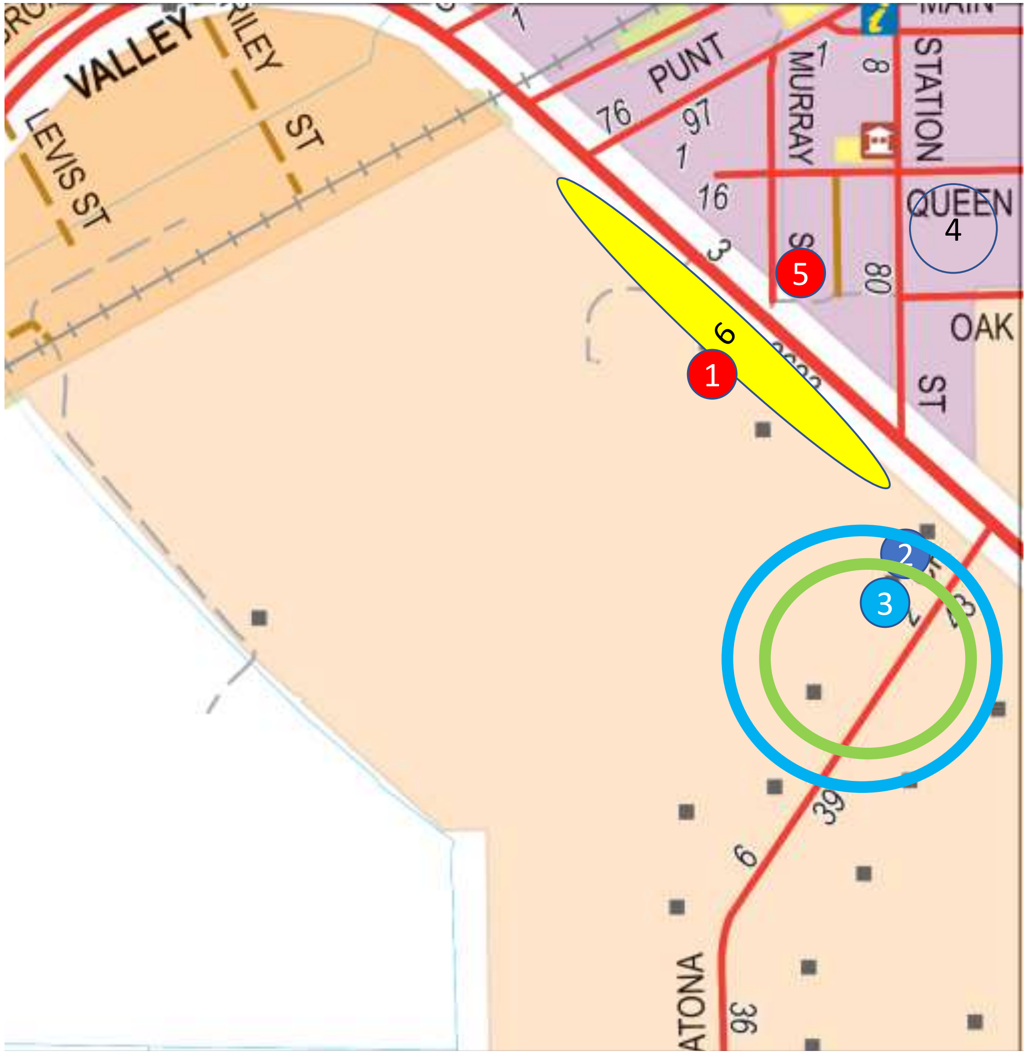
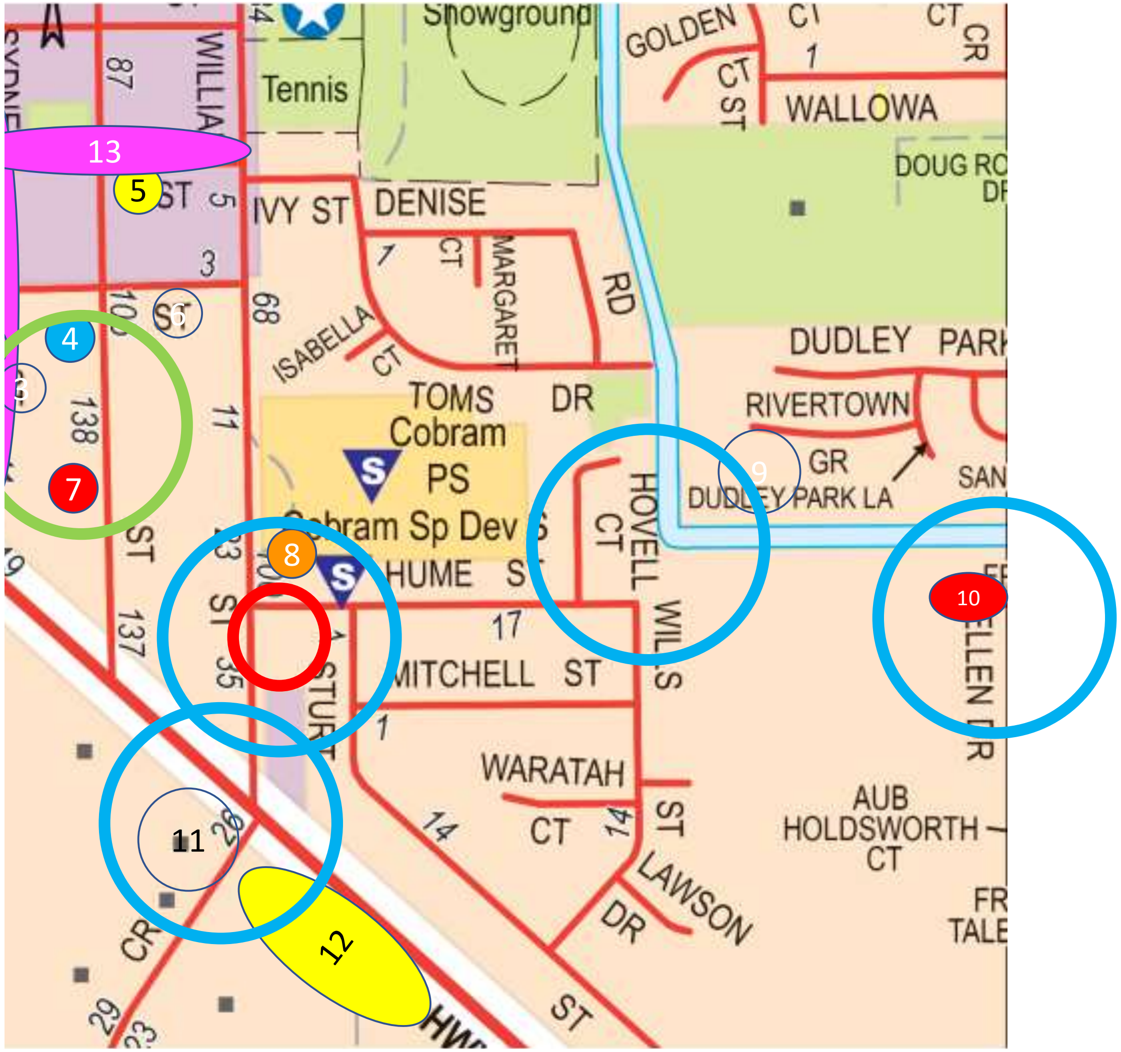


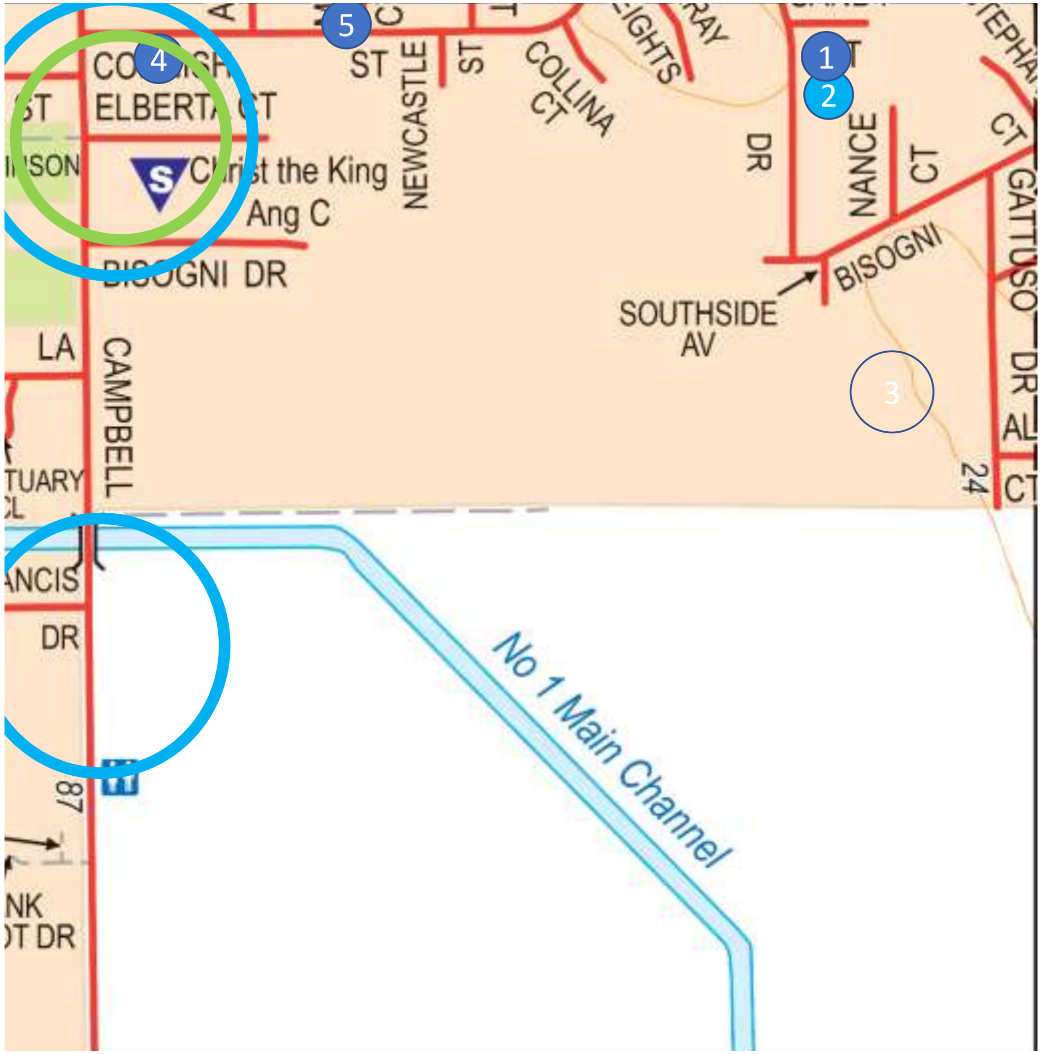
10. COBRAM

1. Feijoa
2. Olives
3. Apples, pears
4. Figs, pomegranates, plums apples
5. Plums
6. Indian figs



11. COBRAM

1. Prunus street trees
2. Apricot, peach
3. Citrus, apples, stone fruit (under netting)
4. Citrus
5. Citrus, figs
6. Olives, grapes, citrus, loquats
7. Plums, peach
8. Loquat
9. Citrus, peach, apple, plum
10. Plum
11. Olives, figs, apricots, pomegranate, Indian figs
12. Indian figs
13. Prunus street trees



12. COBRAM

1. Citrus
2. Apple
3. Large deciduous fruit orchard
4. Citrus
5. Citrus

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13. COBRAM

1. Citrus
2. Persimmons
3. Avocado
4. Indian figs
5. Abandoned orchard

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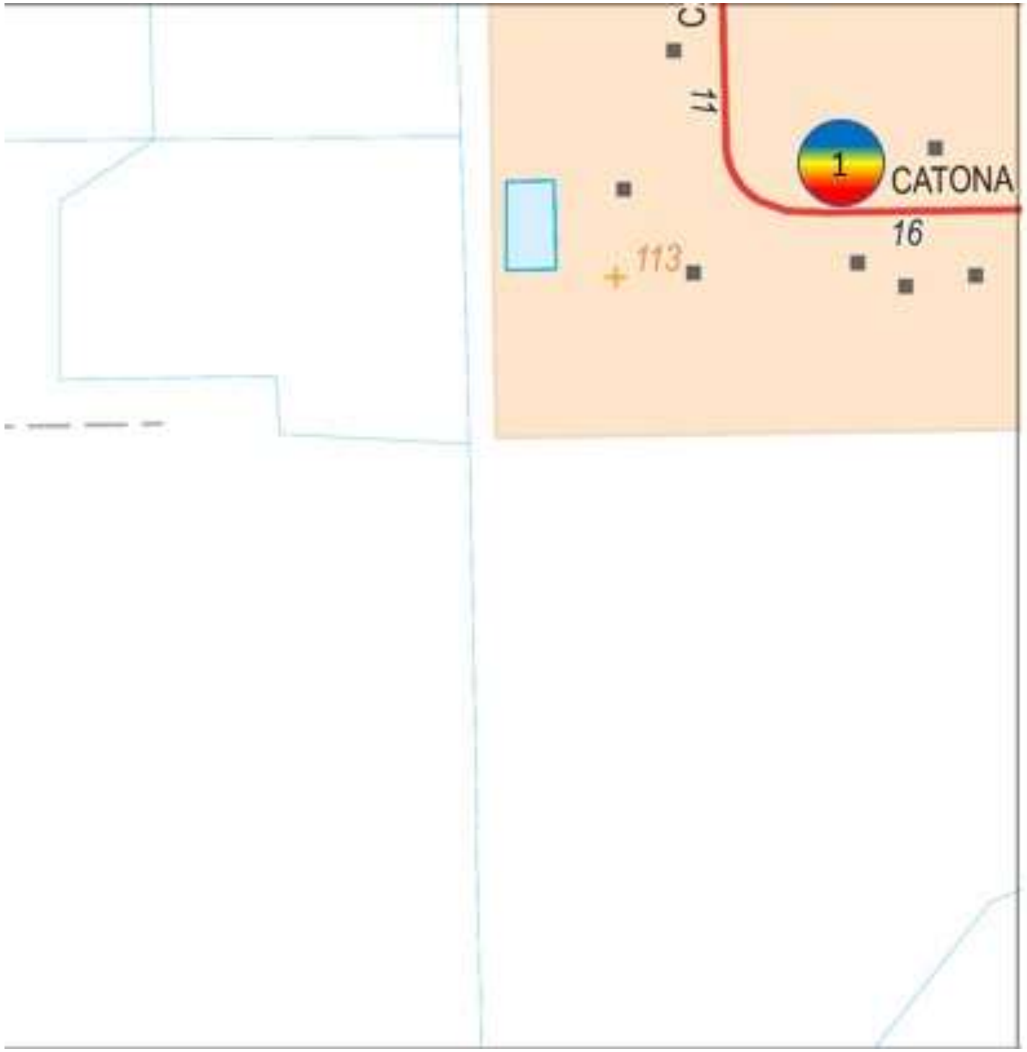

14. COBRAM

1. Figs, pome fruit, olives, plums

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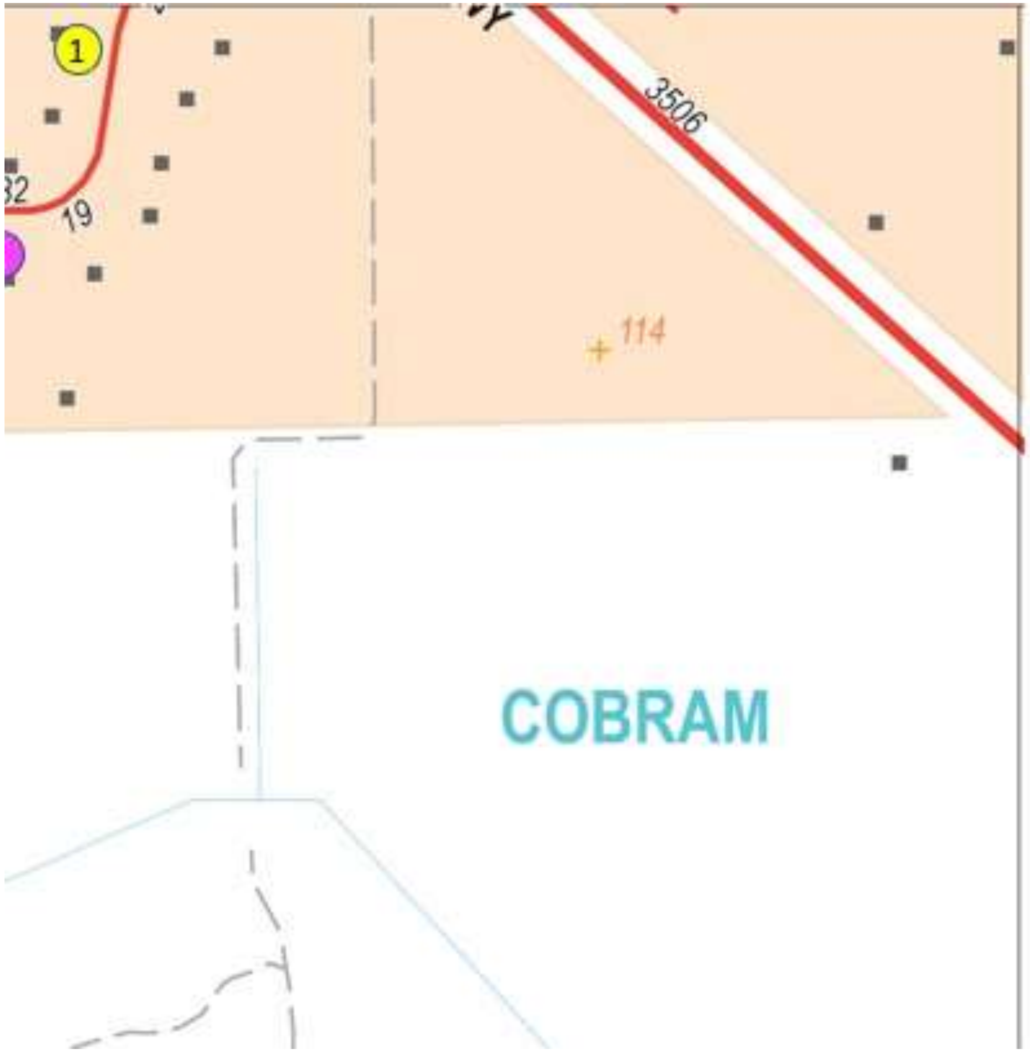
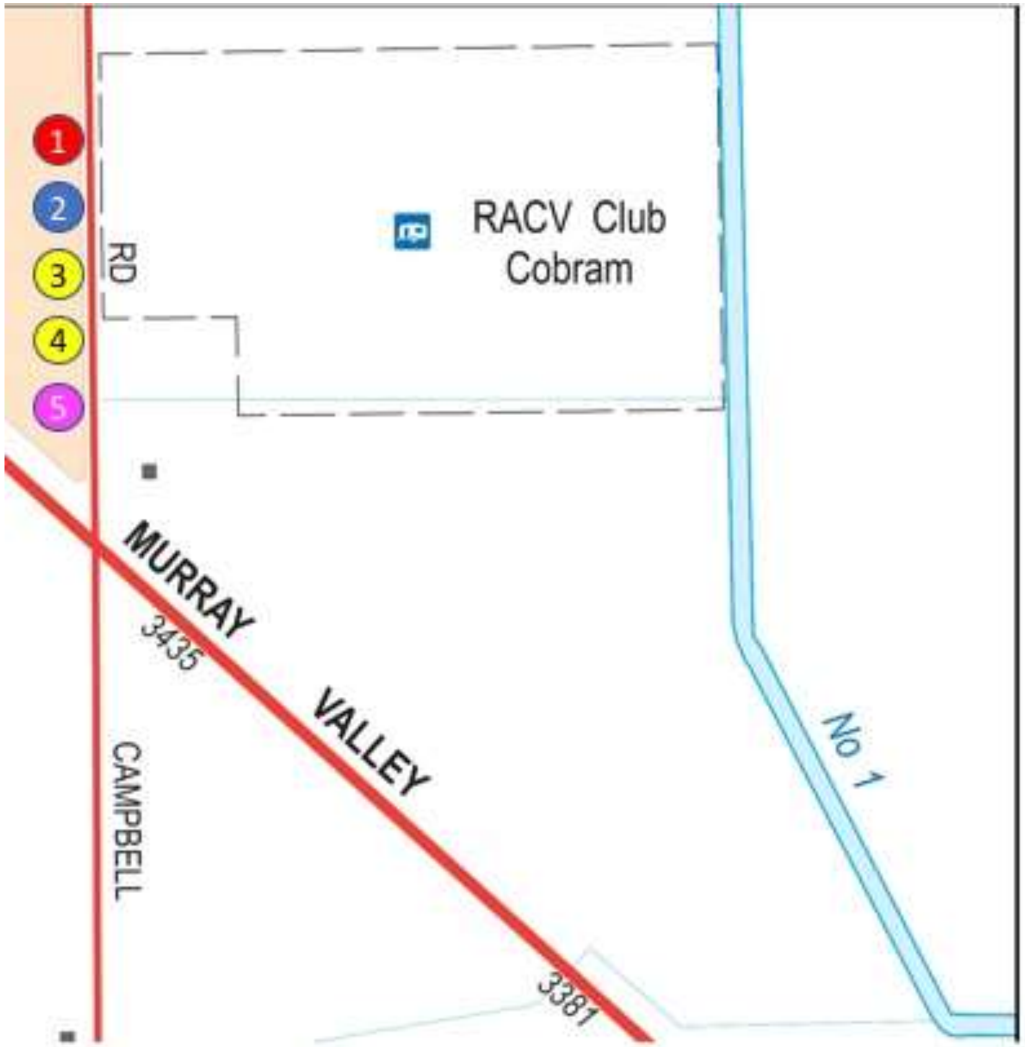


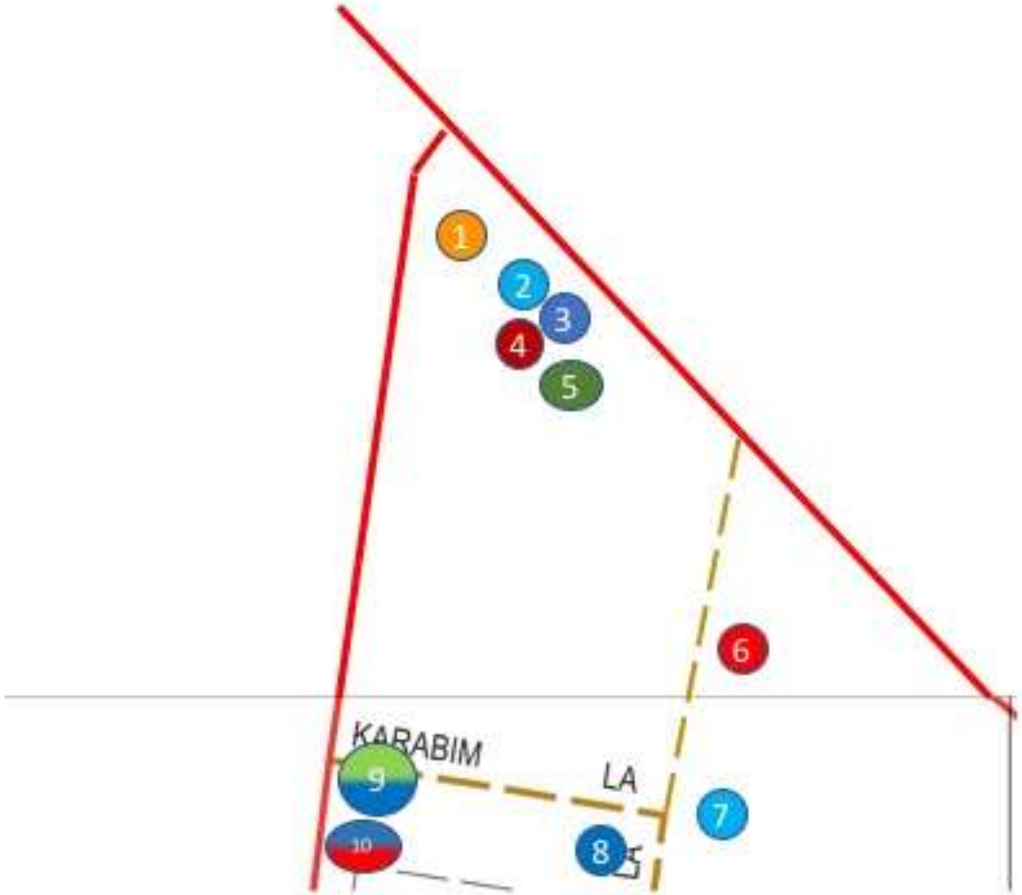
15. COBRAM

1. Figs
2. Prunus along driveway



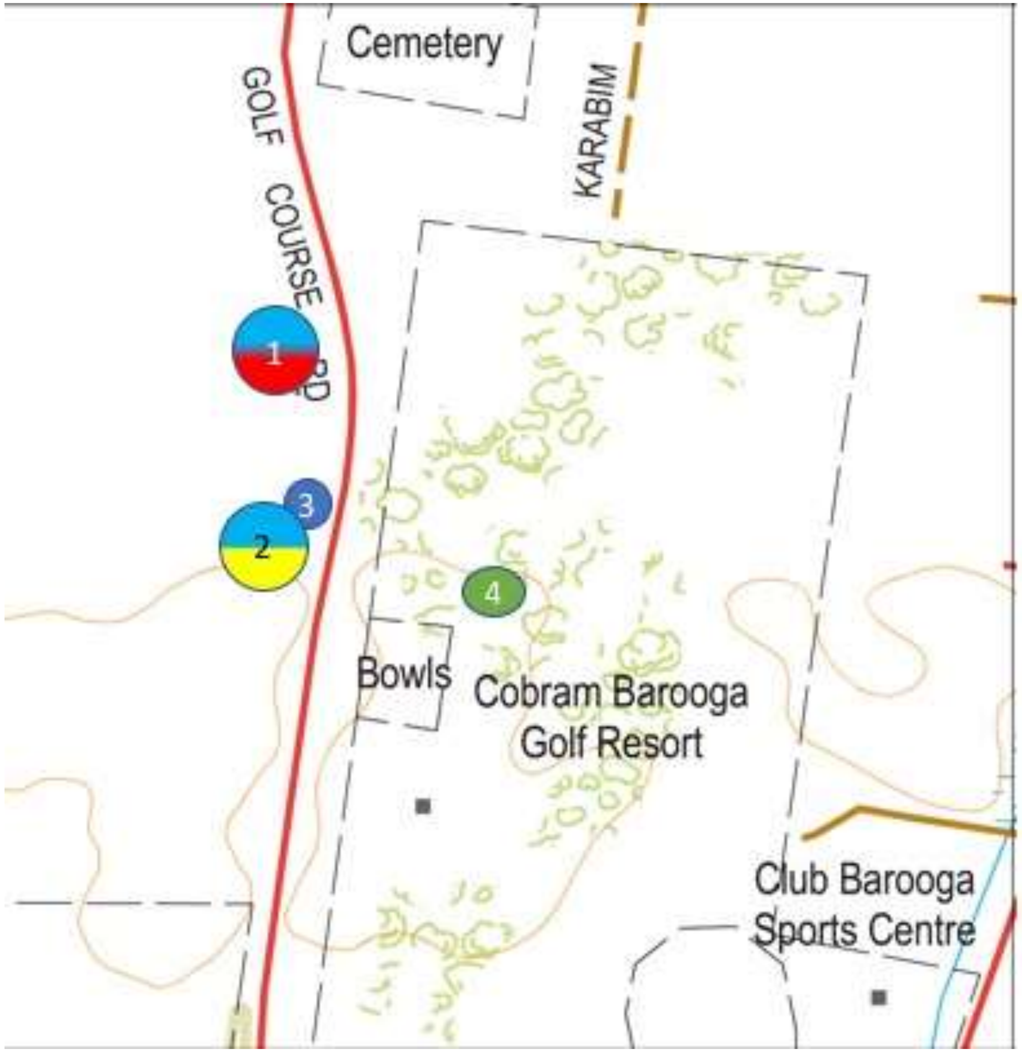
16. COBRAM

1. Persimmons
2. Olives
3. Indian figs
4. Pomegranates
5. Cherry



1. BAROOGA

1. Mulberry
2. Apple
3. Citrus
4. Peach
5. Vegetable patch
6. Apple
7. Apple, vegetable patch
8. Olives
9. Citrus trees, apple, grapes, olive
10. Stone fruit, citrus (netted)



2. BAROOGA

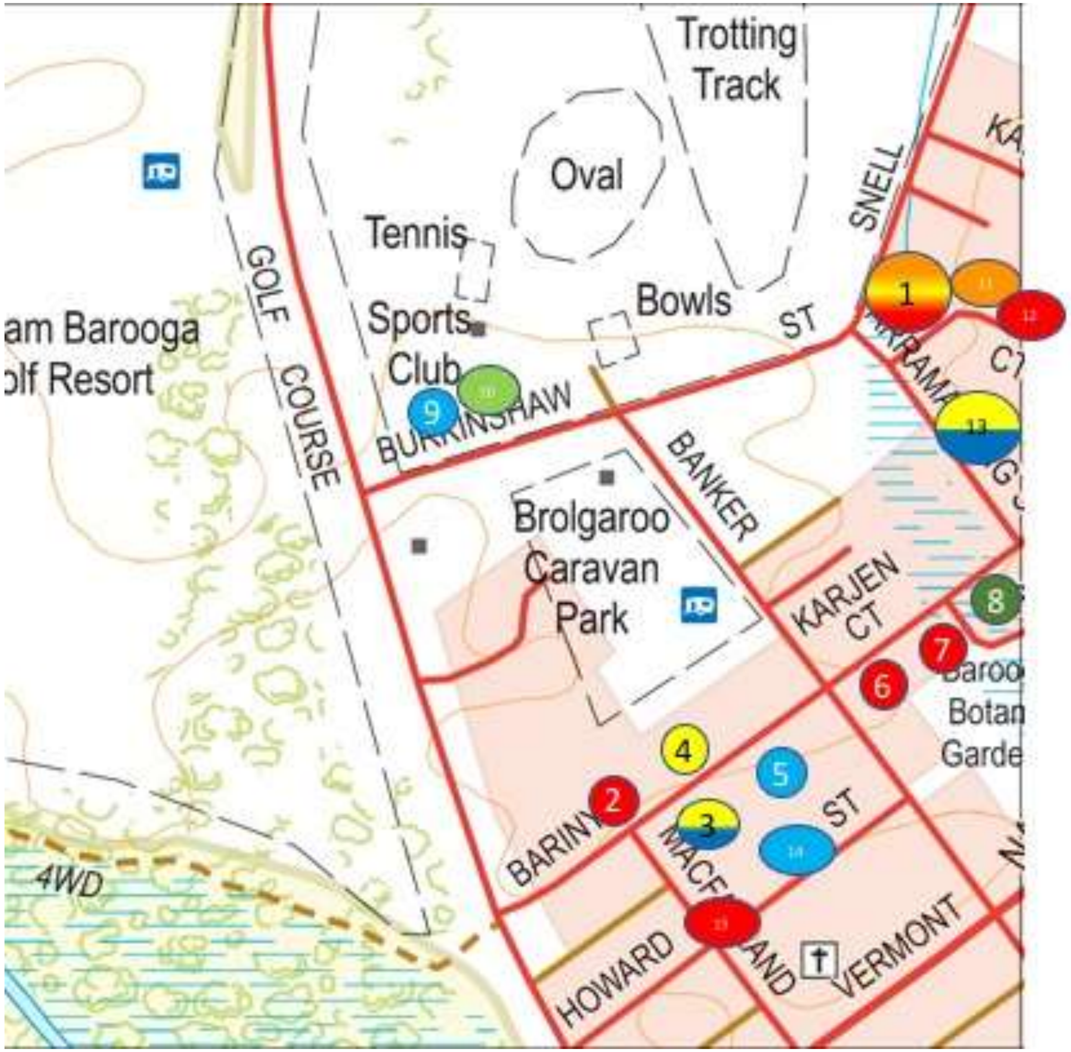
1. Citrus (2), Plums (2), Apple
2. Citrus, fig
3. Avocadoes
4. Asian pears

3. BAROOGA

1. Asian pears

4. BAROOGA

1. Apricots, peaches
2. Peach, olives, apricots, citrus
3. Peaches, grapes
4. Asian pears (10)



5. BAROOGA

1. Loquats, peaches, figs – many fruit trees
2. Peaches (several)
3. Citrus (late), apples, figs
4. Pomegranate
5. Citrus
6. Feijoa
7. Peach
8. Asian pears
9. Citrus (late)
10. Asian pears
11. Apricot
12. Peach
13. Weeping mulberry, Prunus, figs, citrus (late), avocadoes and other fruit
14. Apple
15. Peach

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6. BAROOGA

1. Citrus (late)
2. Citrus, grapes
3. Citrus
4. Citrus (late)
5. Apple

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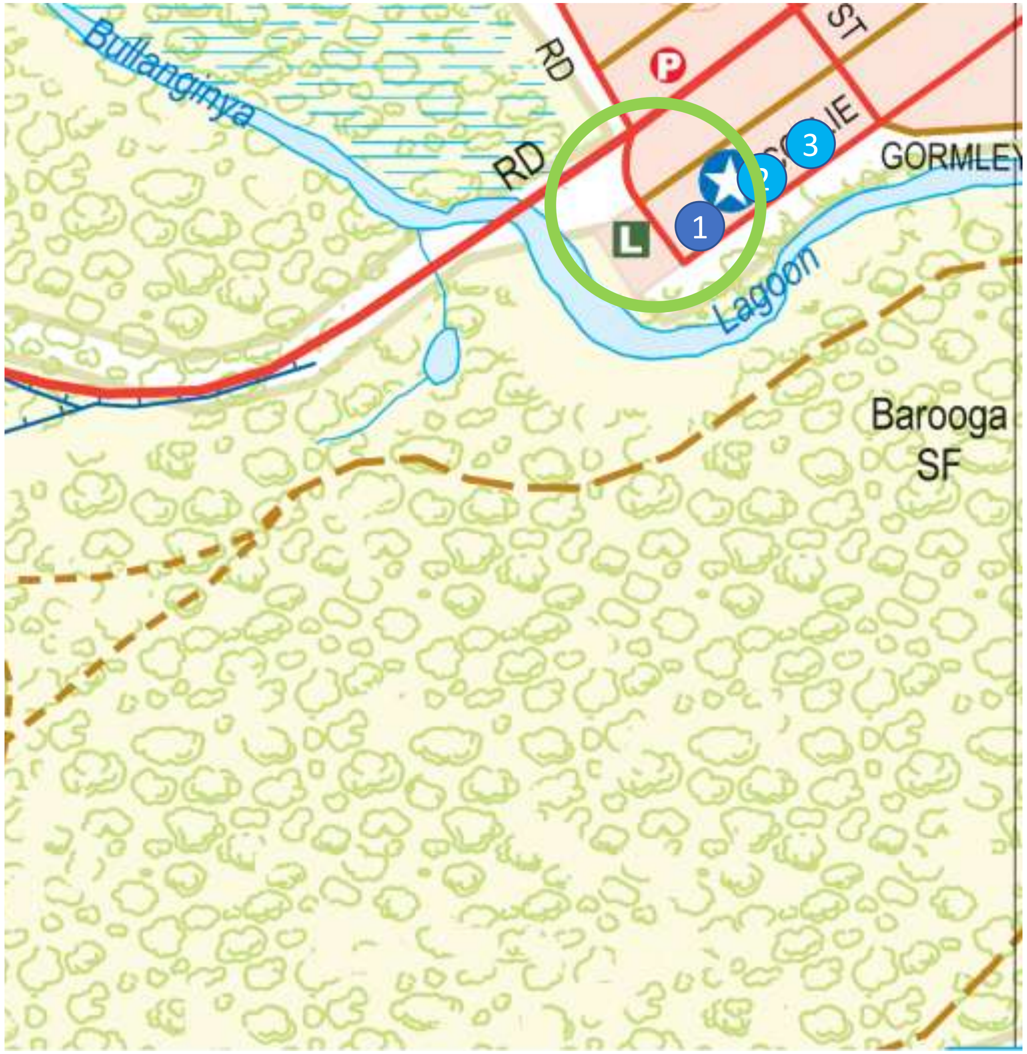
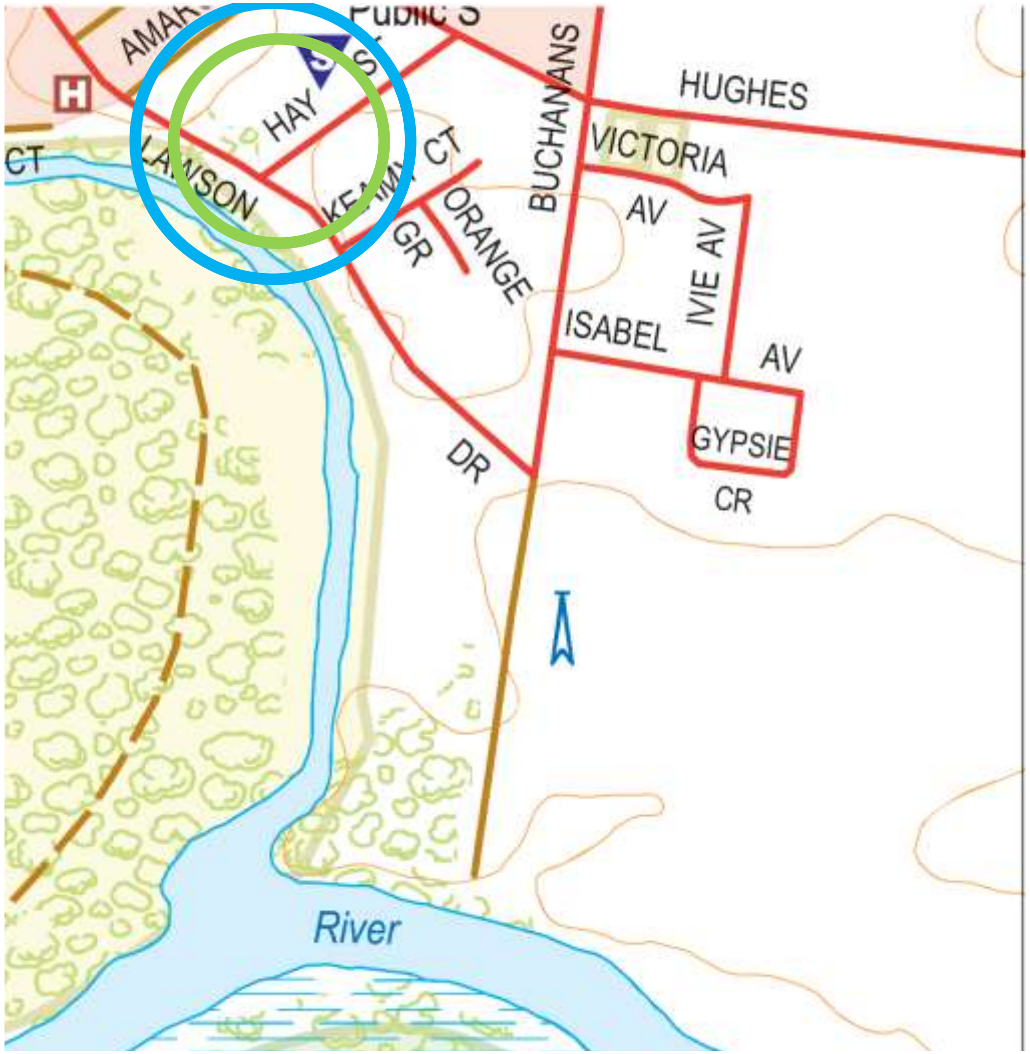


7. BAROOGA

1. Citrus (late)
2. Citrus
3. Citrus


HUGHES
BUCHANANS
VICTORIA
AV
HAY
LAWSON
CT
ORANGE
GR
ISABEL
IVIE AV
AV
GYPSIE
CR
DR
River

8. BAROOGA

MAPS SHOWING RURAL AREAS WITHIN TARGET REGION 6KM FROM COBRAM POST OFFICE

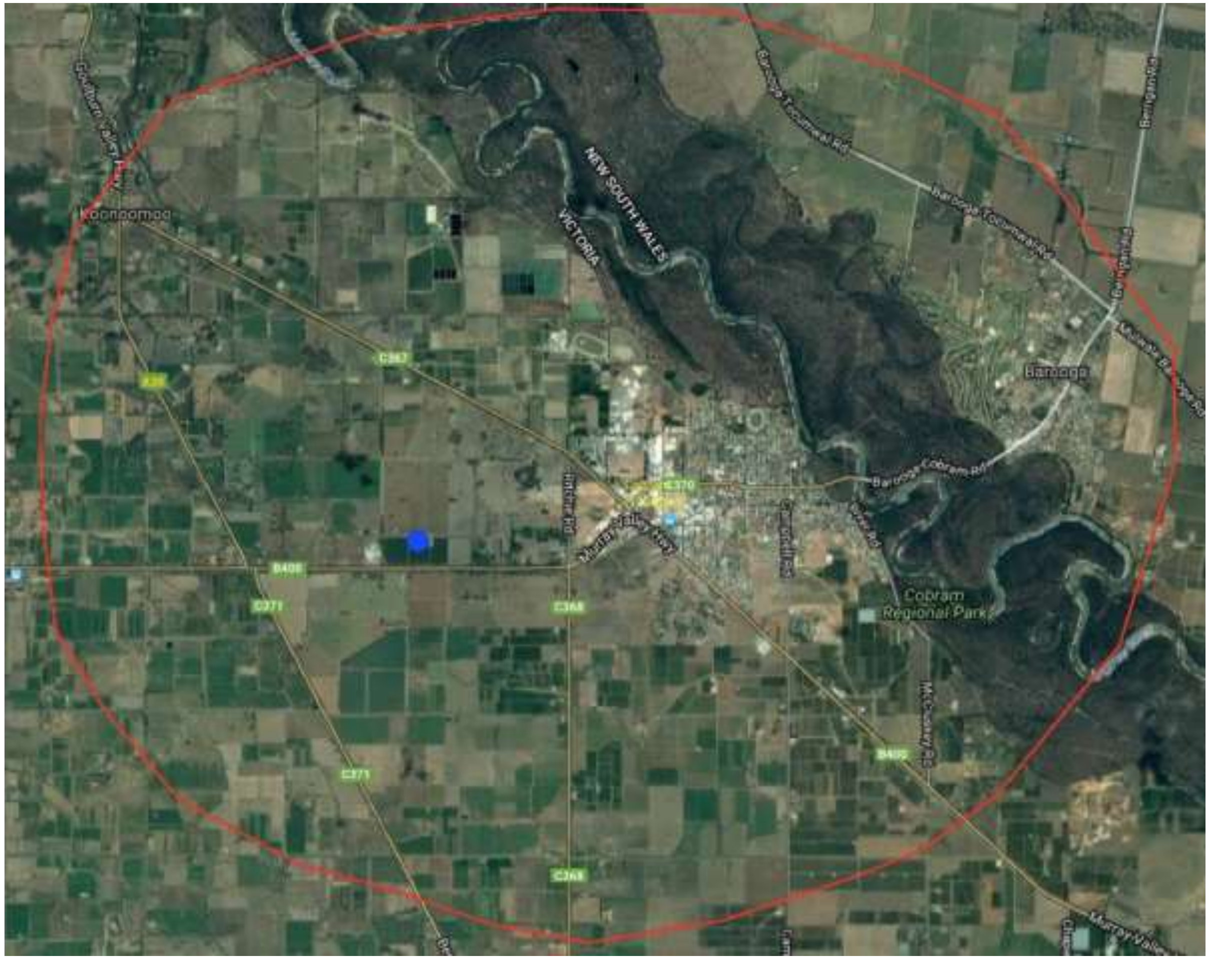


Figure 5. Target area – Within 6km radius of Cobram Post Office

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From Google Earth (July 2017): 1 square kilometre north-west of Cobram Post Office

From Google Earth (July 2017): 6x6 square kilometres south-east of Cobram Post Office

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From Google Earth (July 2017): 6x6 square kilometres north-east of Cobram Post Office

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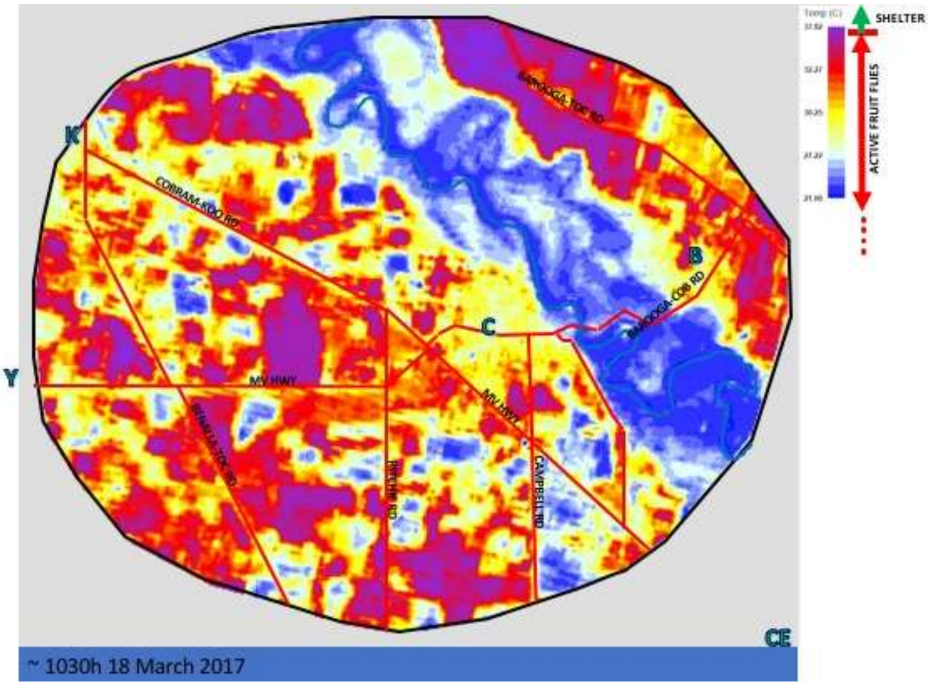
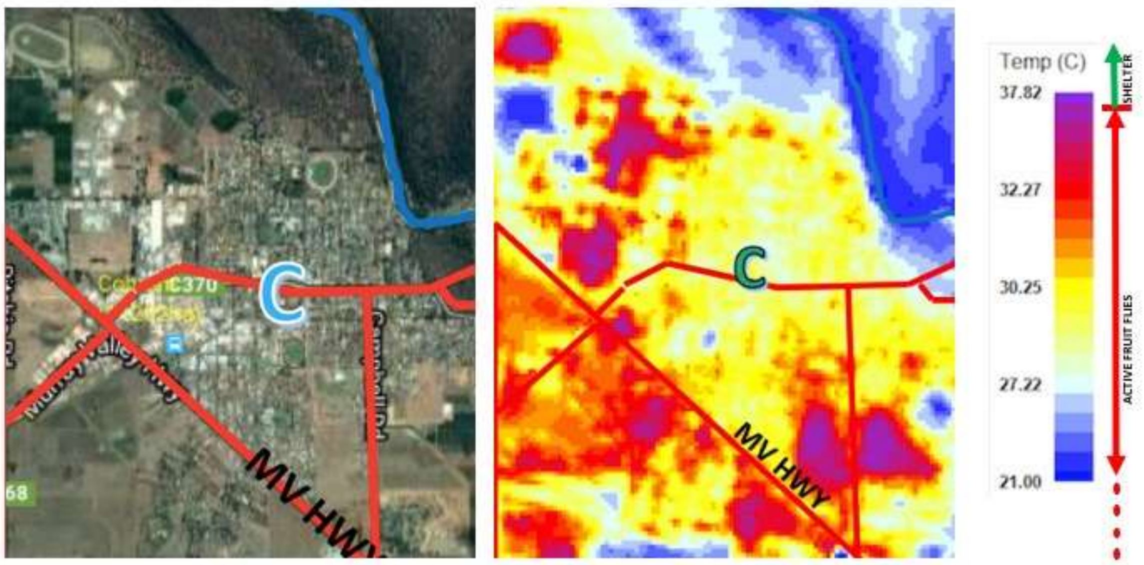
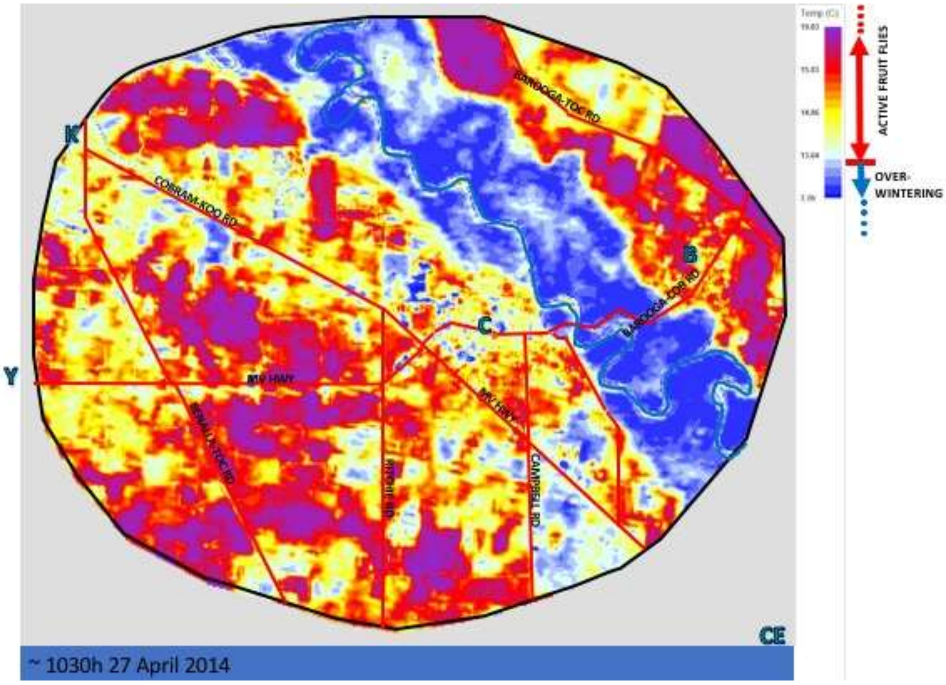
From Google Earth (July 2017): 6x6 square kilometres south-west of Cobram Post Office

MAPS SHOWING THERMAL IMAGES OF TARGET REGION DURING THE YEAR INCLUDING LIKELY QFF ACTIVITY

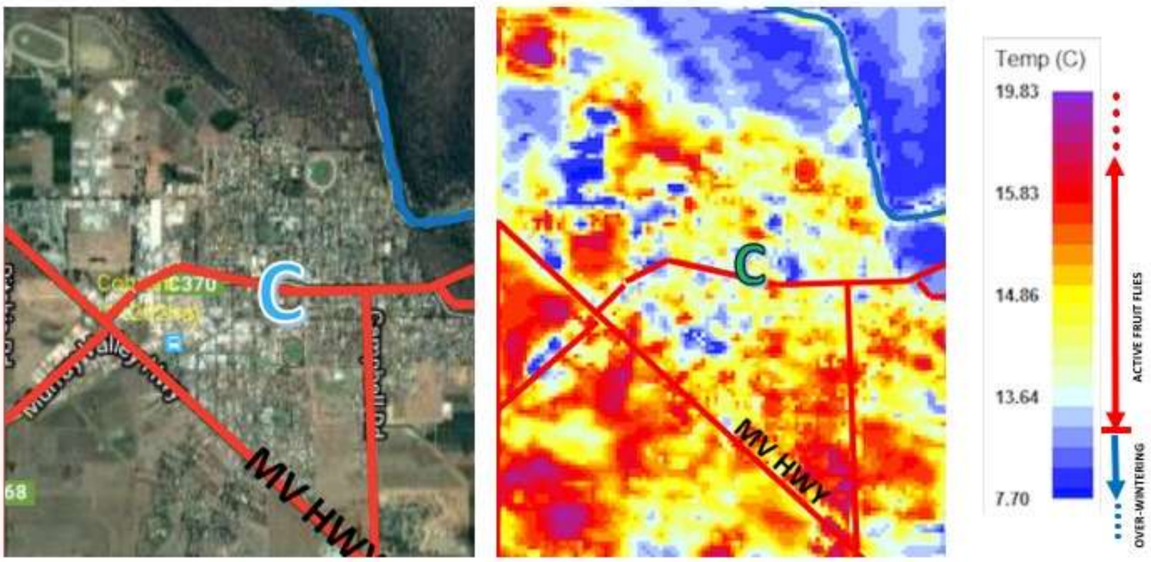




~ 1030h 18 March 2017



~ 1030h 27 April 2014



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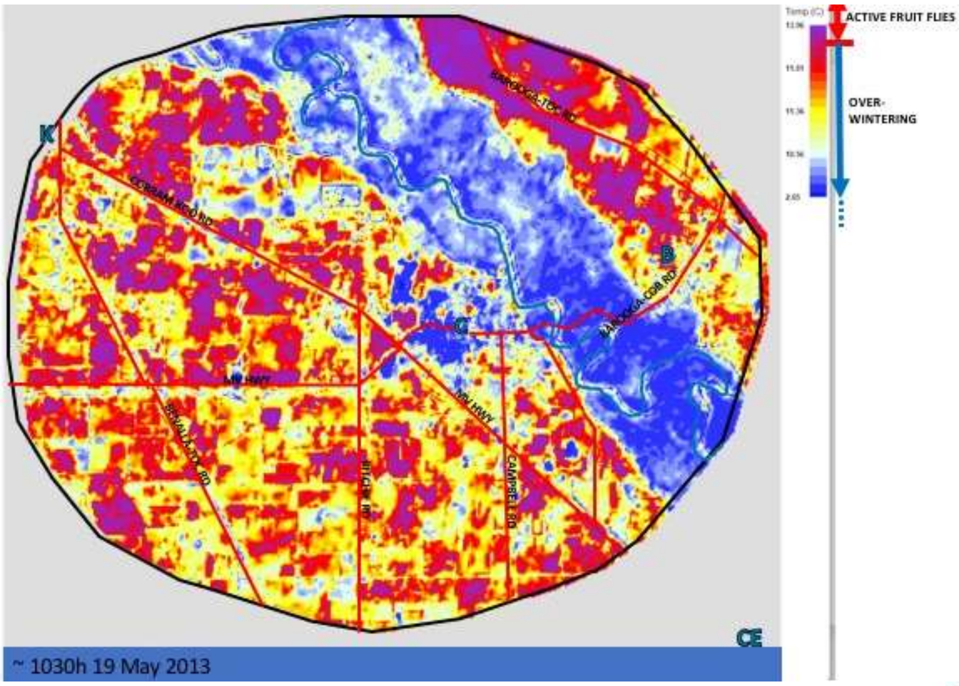

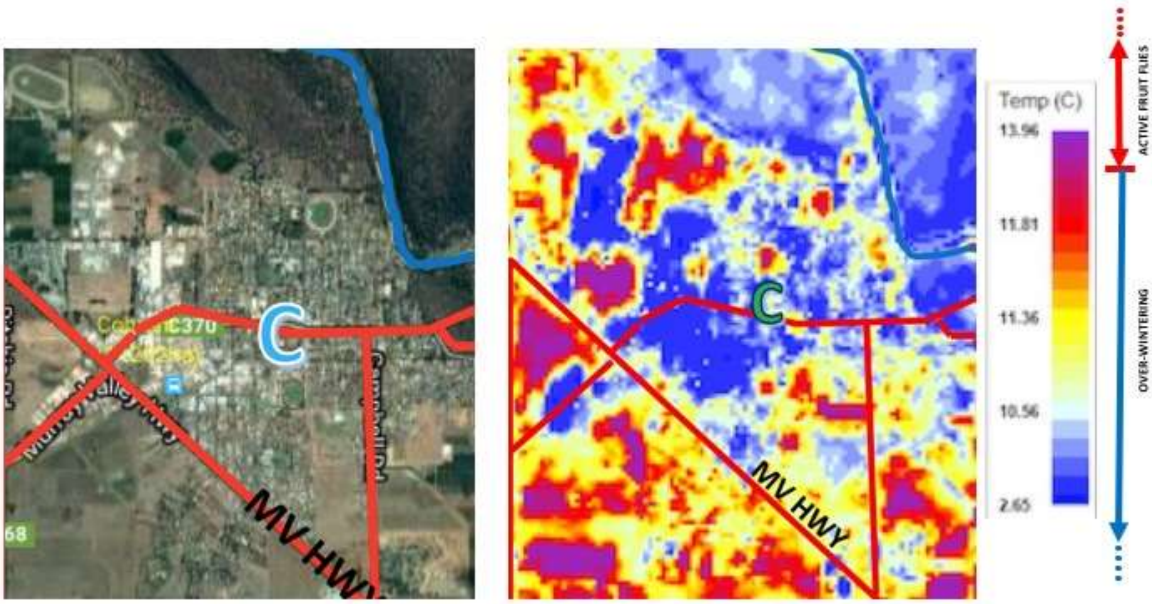

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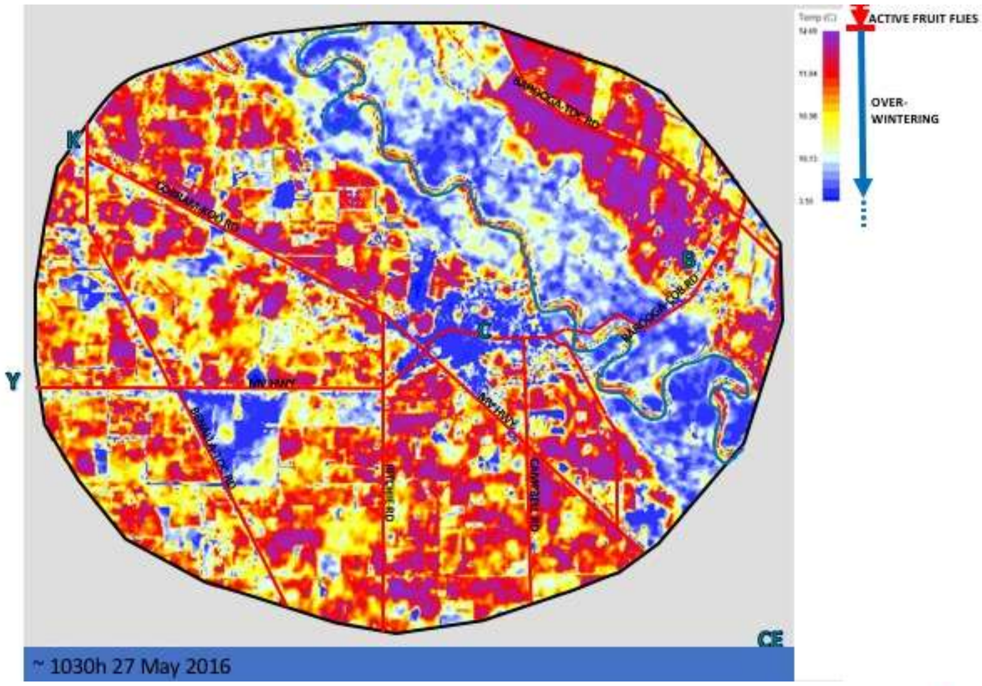
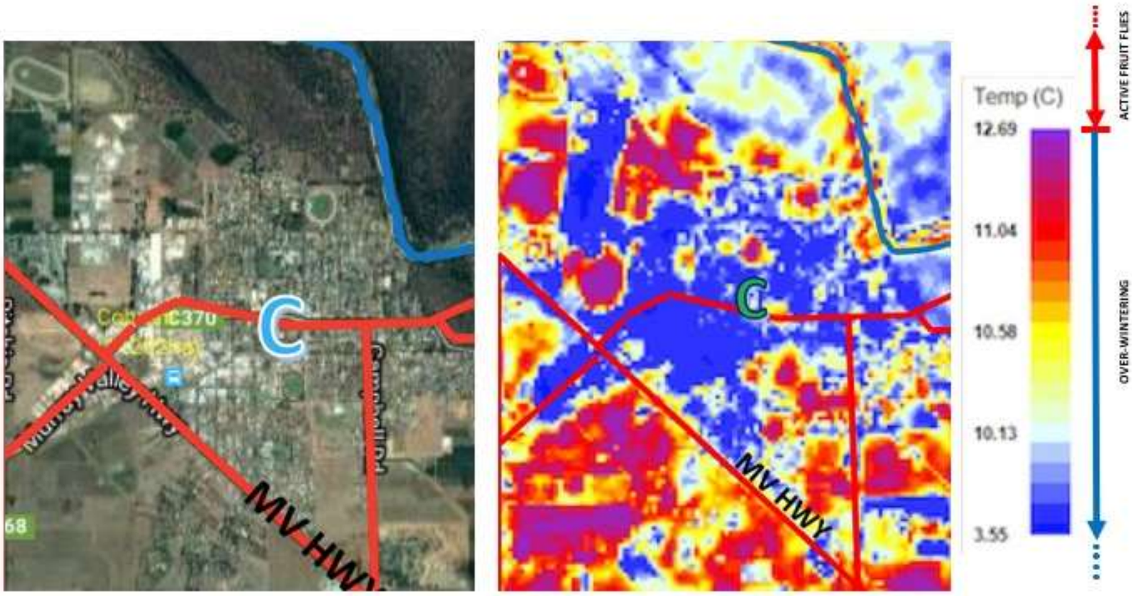


~ 1030h 27 May 2016



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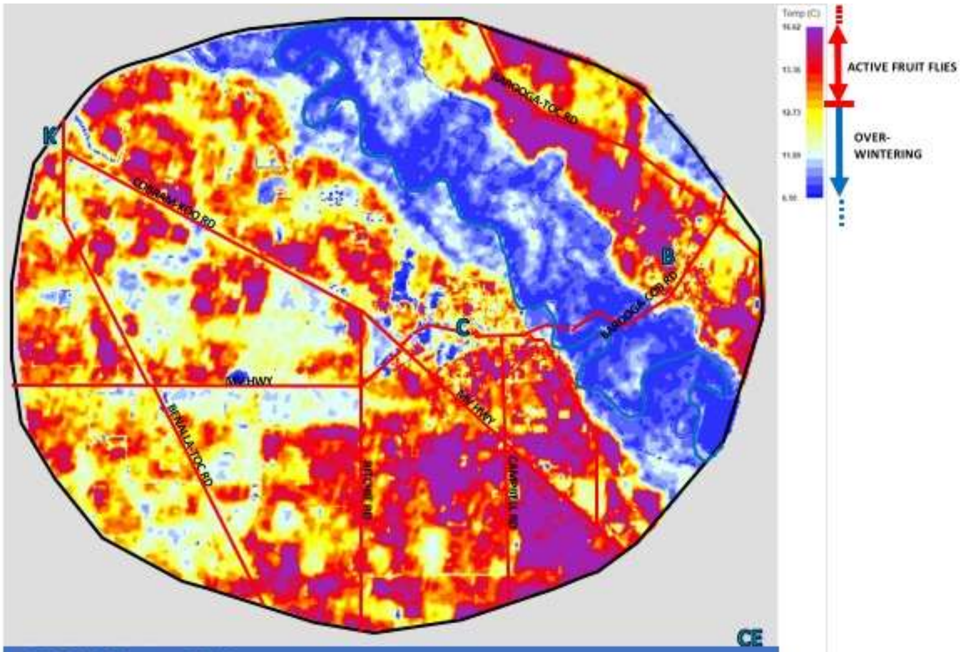
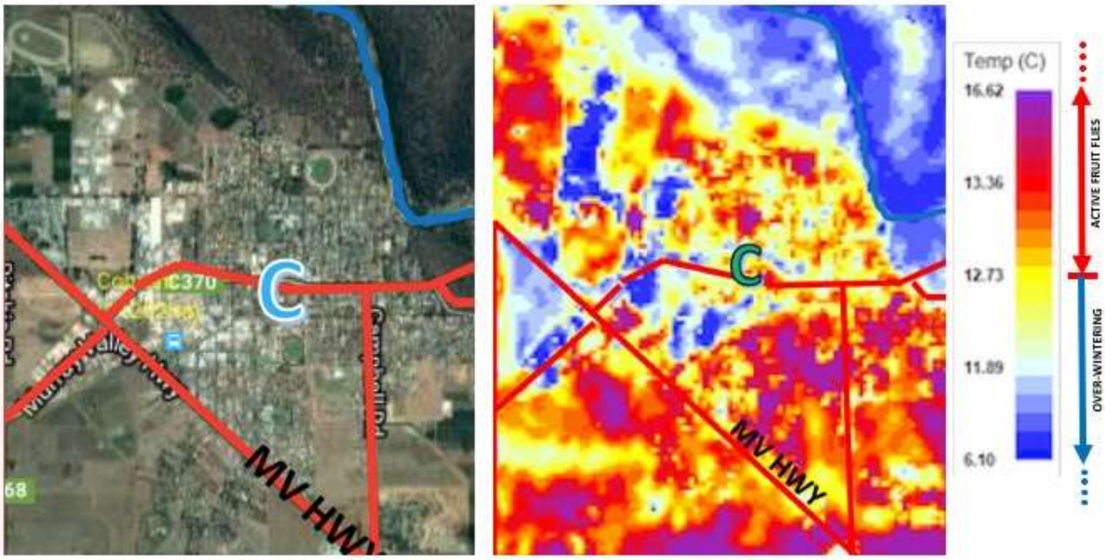


~ 1030h 15 August 2016



~ 1030h 15 August 2016

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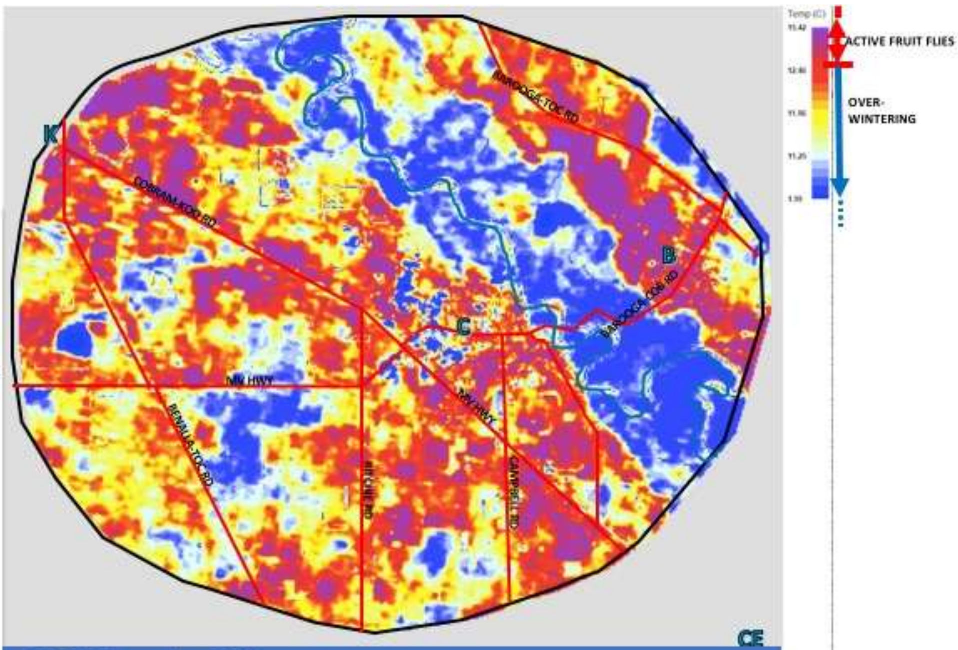
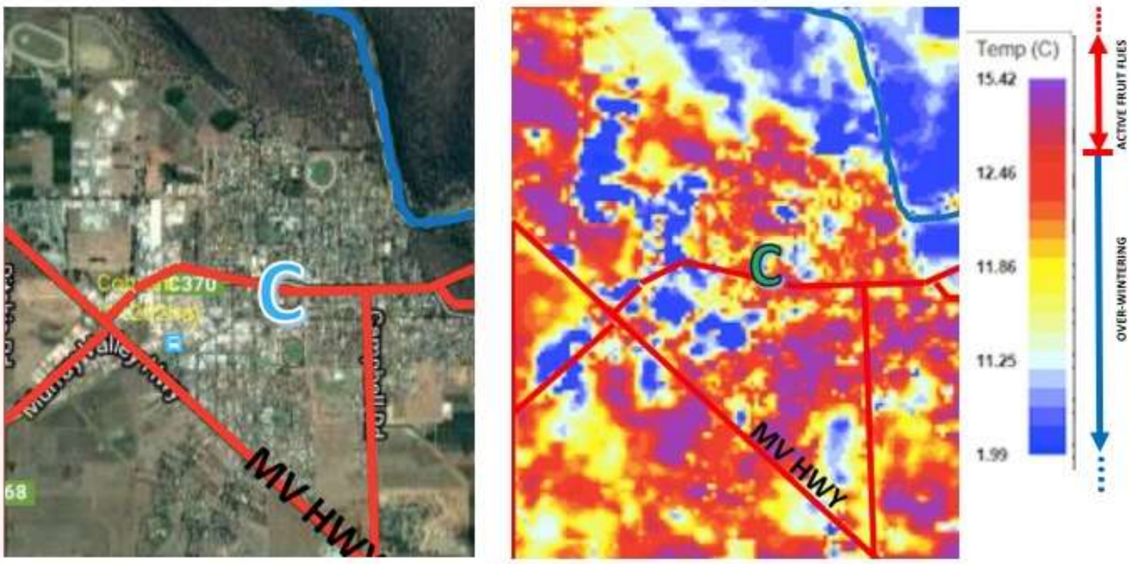


~ 1030h 2 September 2014



~ 1030h 02 September 2014

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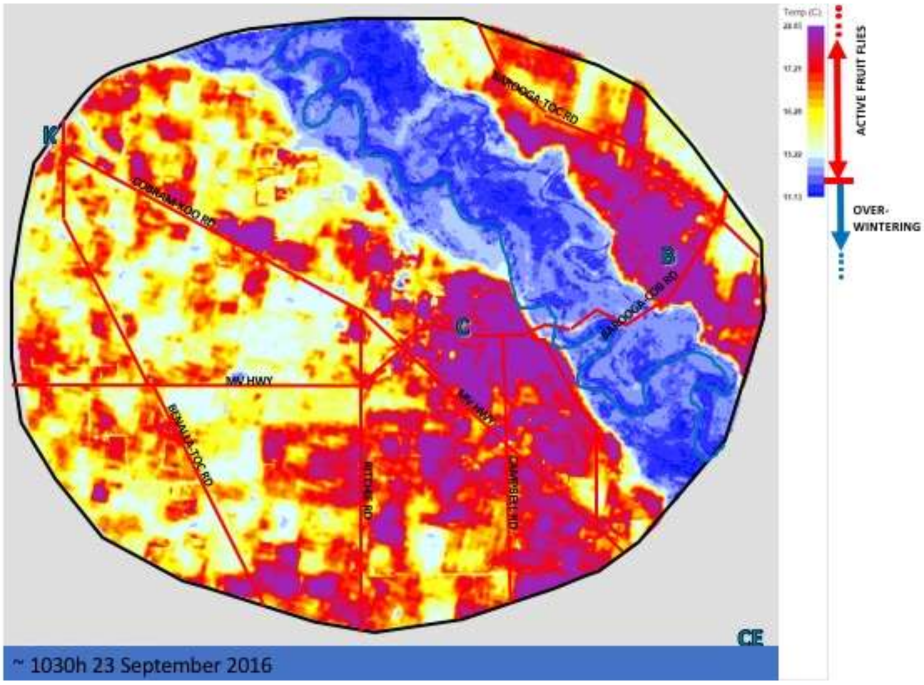
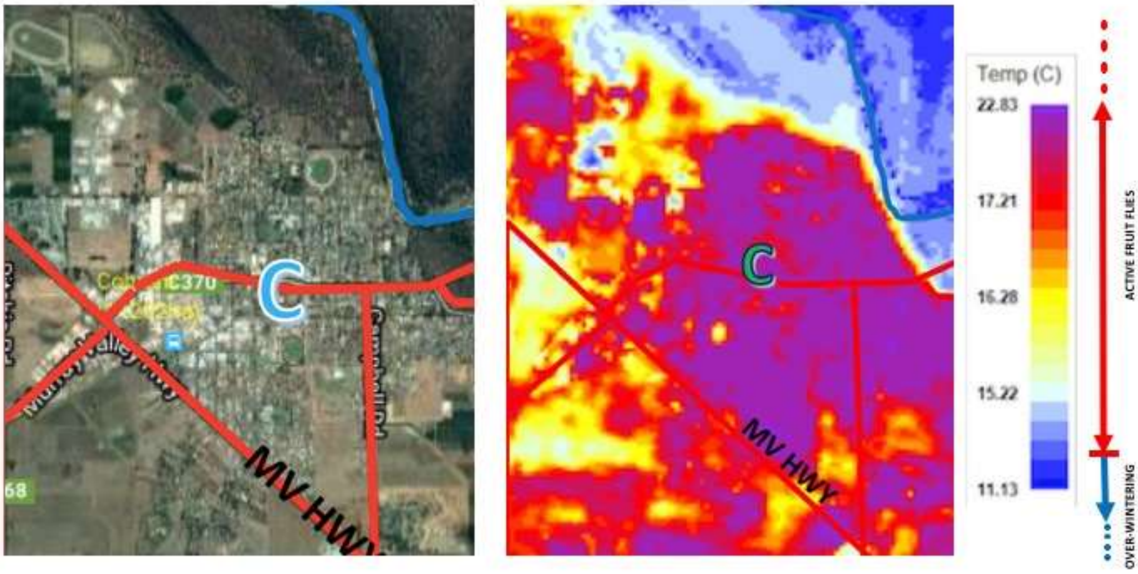
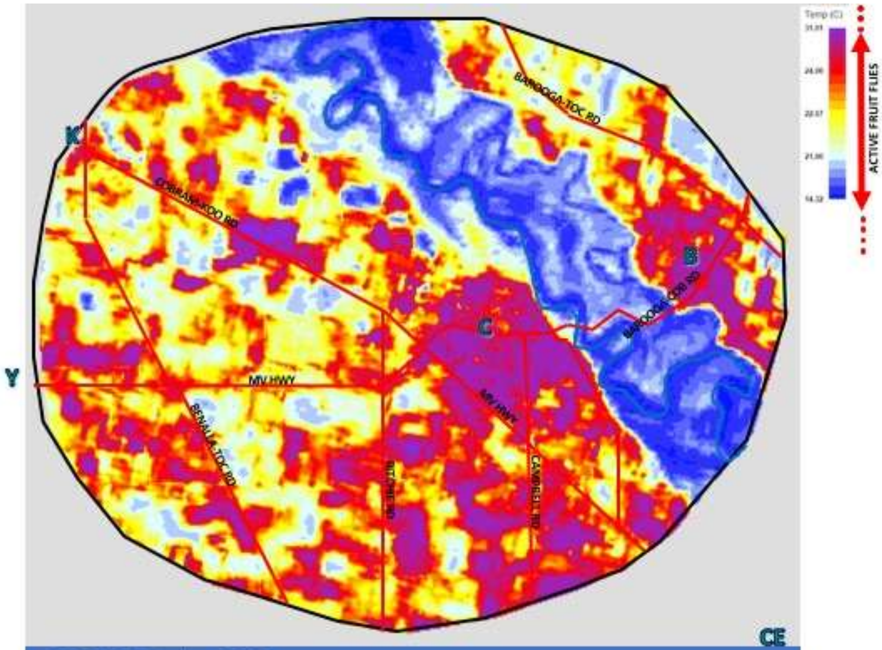
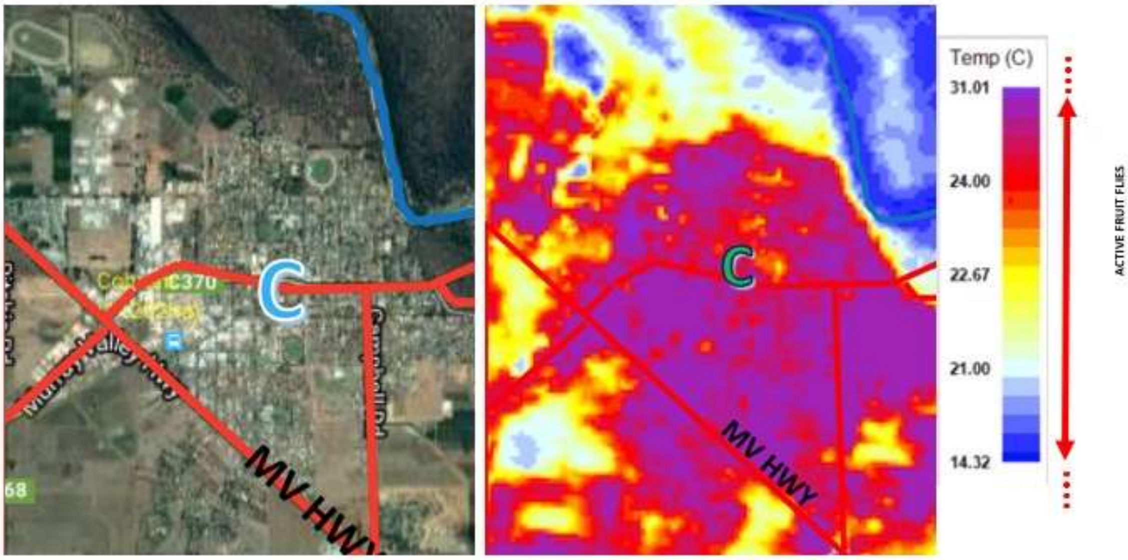




~ 1030h 23 September 2016



~ 1030h 25 October 2016



~ 1030h 26 October 2016

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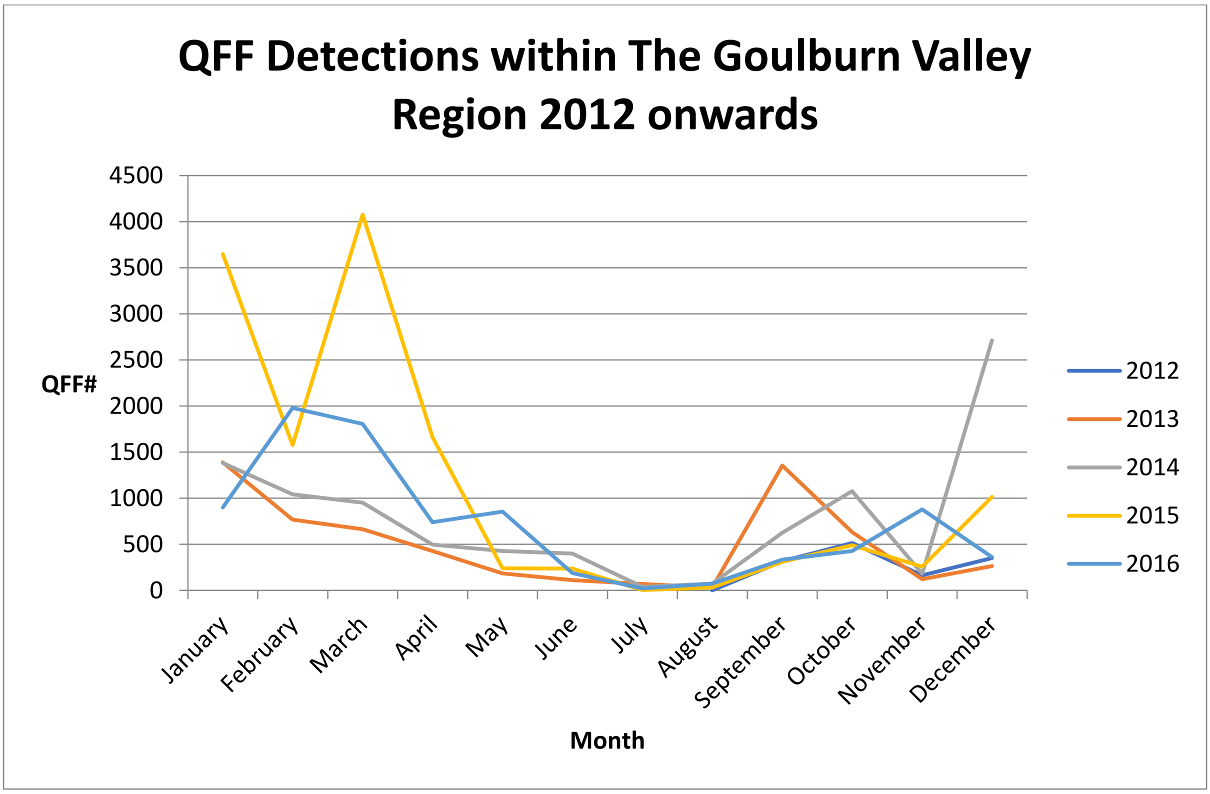
GRAPH OF QFF DETECTIONS IN DEDJTR TRAPS IN THE GOULBURN VALLEY REGION (2012 TO 2016)



MAP SHOWING LOCATIONS OF DEDJTR TRAPS AND TRAP CAPTURES FOR COBRAM (2012 TO 2017)

DEDJTR trap locations in and around Cobram. Numbers: The larger is the total number of flies trapped in 2012 to 2017 (as of end of May) and the lower is the total flies trapped during the winter months of those years.